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LICHEN AND BARK MONITORING PROGRAMME
Southwest Thunder Bay District
1970-71 and 1981-83

APIOS
Acidic Precipitation in
Ontario Study
Terrestrial Effects

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LICHEN AND BARK MONITORING PROGRAMME

FINAL REPORT

Prepared for:

The Ontario Ministry of the Environment
Acidic Precipitation in Ontario Study
Terrestrial Effects

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March, 1988.

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EXECUTIVE SUMMARY

In 1970-71 a study of ground and epiphyte vegetation was carried out in a 10,000 km^2 area in southwest Thunder Bay District. Included in this study was a sampling programme for lichens and for bark. In 1980, because of increasing concern with acidic precipitation, the Ontario Ministry of the Environment became interested in the 1970-71 samples. These samples could provide baseline data for present and future comparisons. Therefore, in 1980, some of the 1970-71 sites were resampled, using the techniques of the earlier study.

Analyses were carried out for 22 elements, including the metals Al, Cu, Cd, Cr, Fe, Hg, Mn, Mo, Ni, Pb, and Zn, the metalloid As and for F. Plant nutrient elements tested for were Ca, K, Mg, Na, B, Cl, N, P, and S.

This report contains the data and analyses for 1970-71 and 1981-83 lichen and bark samples. All analytical results are presented in tables in the report as baseline data. Statistical analyses of these data show that for most elements there have been no significant changes during the 13-year study period. However, the statistical analyses also indicate that in 1970-71 at least some elements had comparatively elevated quantities (Fe, Al, As, Hg, and S). Since 1970 the data indicate that several of the elements decreased significantly (Al, Fe, Hg, As, N, and P, and probably Cr and Pb). Correlation analyses indicate that both local emissions and long-range transport of emission are involved in elemental quantitities. Correlation also indicates that Lake Superior may have an effect on deposition levels of some heavy metals.

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INTRODUCTION

INTRODUCTION

In 1970-71 a vegetation-air quality sampling programme was carried out in southwest Thunder Bay District. A nickel smelter had been proposed for Pardee Township (40 km southwest of Thunder Bay) and this sampling programme was to be part of a pre-start-up study. In fact, the smelter was not built. There is, however, a very large ore body in Pardee Township, and there is still current interest in its exploitation. The primary purpose of this pre-development study was to provide baseline data for present and future comparative evaluation, with the major emphasis on documenting the epiphyte and ground vegetation. Secondary purposes were to collect lichen, bark, and soil samples for various analyses.

In 1980, because of increasing public concern with "acid rain", these 1970 samples came to be of interest to the Ontario Ministry of the Environment as part of the APIOS programme (Acidic Precipitation in Ontario Study). These 1970 samples could provide data for comparison with recent samples. Therefore, further samples were collected in 1981 and in 1983. The current project for the Ministry is to provide a final report including statistical comparisons concerning 1970-71 and 1983 samples of lichen material (*Cladina mitis* s.l., *Umbilicaria* spp., *Parmelia sulcata*, and *Evernia mesomorpha*). Although the original proposal was for lichen material only, this report will also provide bark sample information for some tree species from collections in 1970-71 and again in 1981.

All lichen species were chosen in 1969 on the basis of availability. *C. mitis* s.l. is a common ground lichen in the study area. *Umbilicaria muhlenbergii* is a common rock lichen (a few collections are *U. vellea* from sites where there was no *U. muhlenbergii*). *P. sulcata* is a very common foliose epiphyte and *E. mesomorpha* is a common fruticose epiphyte lichen. Because these are common lichen species, a number of studies have been published relating to them (Le Blanc *et al.*, 1975; Nieboer *et al.*, 1978; Pike, 1978; Richardson & Nieboer, 1981; Kershaw, 1985). The bark collections were also based on availability, with the most common tree species on the study sites being selected for sampling.

1.1 The purposes of this report are:

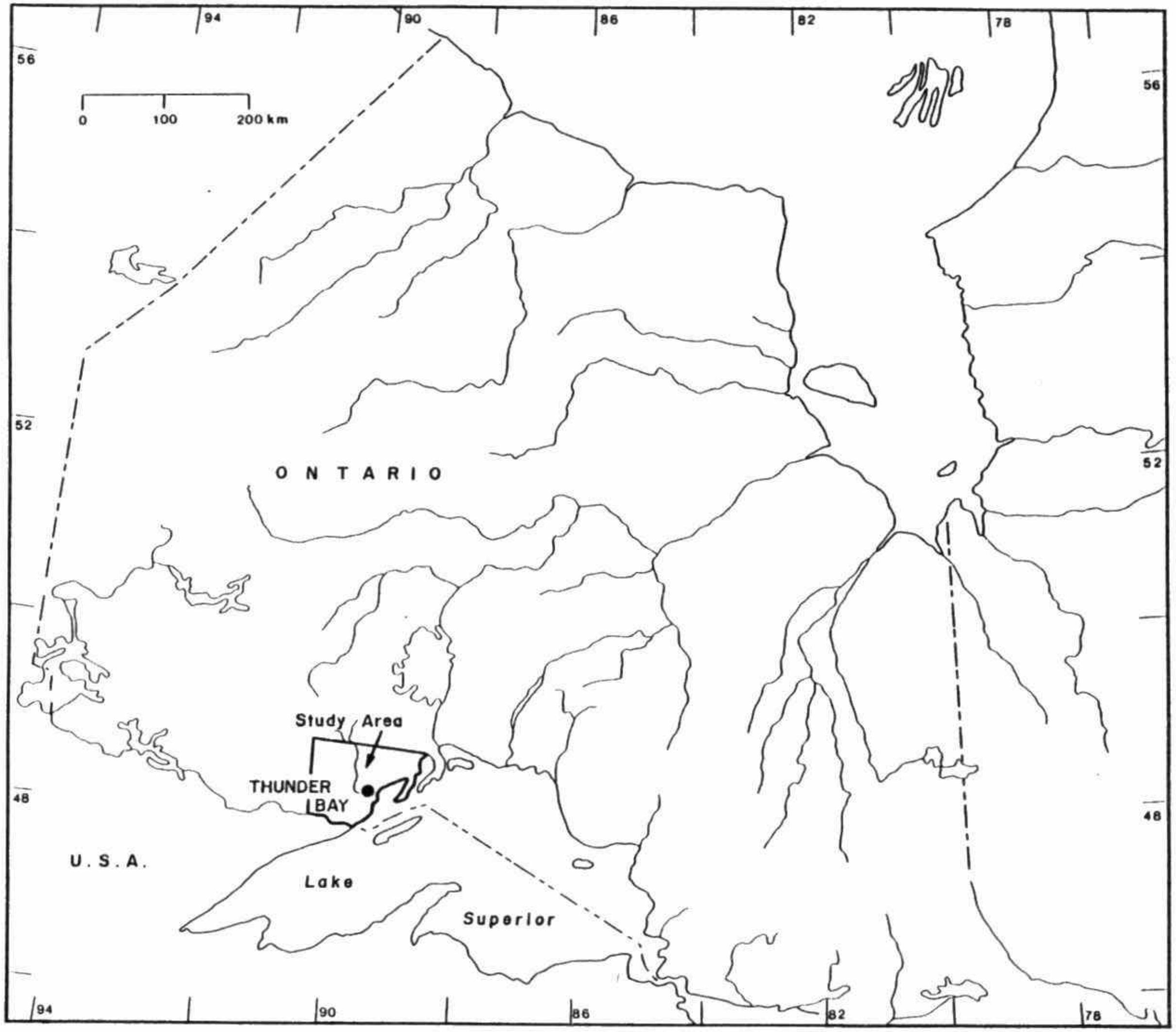
1. To provide baseline elemental data from four sets of lichen species collections from 1970-71 and 1983.
2. To compare the 1970-71 and 1983 lichen data sets and to determine if any statistically significant changes have occurred.
3. To provide elemental baseline data of bark collections from five conifer and four deciduous tree species.
4. To compare the 1970-71 and 1981 bark data sets and to

determine if any statistically significant changes have occurred.

5. To attempt to interpret the lichen and bark data and the data analysis to show possible relationships to air emission sources.

1.2 Study Area Description

The study area is about 10,000 km^2 (3,900 mi^2) in area. Most of the study sites are within 75 km of Lake Superior on the southeastern boundary, which is the major geographical feature of this part of northwestern Ontario (Map A). The northern part of the area is underlain by the ancient, mostly acid crystalline rocks of the Superior Province of the Canadian Shield. The southern part of the area is in the Southern Province of the Canadian Shield, which is mostly basic intrusive diabase rocks as well as various volcanic and sedimentary rocks. The area is mostly a peneplain but there are also strongly broken uplands with elevations of over 500 metres. The soil of the area is complex. There are organic soils and gleysols in poorly drained areas but most of the soils are brunisols, podzols, and luvisols. The climate is Humid Continental modified by Lake Superior. The winters are cold and the summers are cool. There is 70 - 80 cm of precipitation a year with about one-third falling as snow. There is a water surplus, as potential



Map A. Location of Study Area.

evapotranspiration is exceeded by precipitation. The northern area of the study is in the Superior and the Upper English River Sections of the Boreal Forest Region, and southern part is in the Quetico section of the Great Lakes St. Lawrence Forest Region (Rowe, 1972). Throughout the study area white spruce *(Pieea glauca)*, balsam fir *(Abies balsamea)*, white birch *(Betula papyrifera)*, and trembling aspen *(Populus tremuloides)* are common tree species on mesic sites. Jack pine *(Pinus banksiana)* is common on acid sands and well drained sites. Black spruce *(Picea mariana)* is found on thin acid soils of upland areas and on poorly drained lowland organic soils. The southern part of the area is floristically richer than the northern part and black ash *(Fraxinus nigra)*, Manitoba maple *(Acer negundo)*, red maple *(Acer rubrum)*, and sugar maple *(Acer saccharum)* are not uncommon.

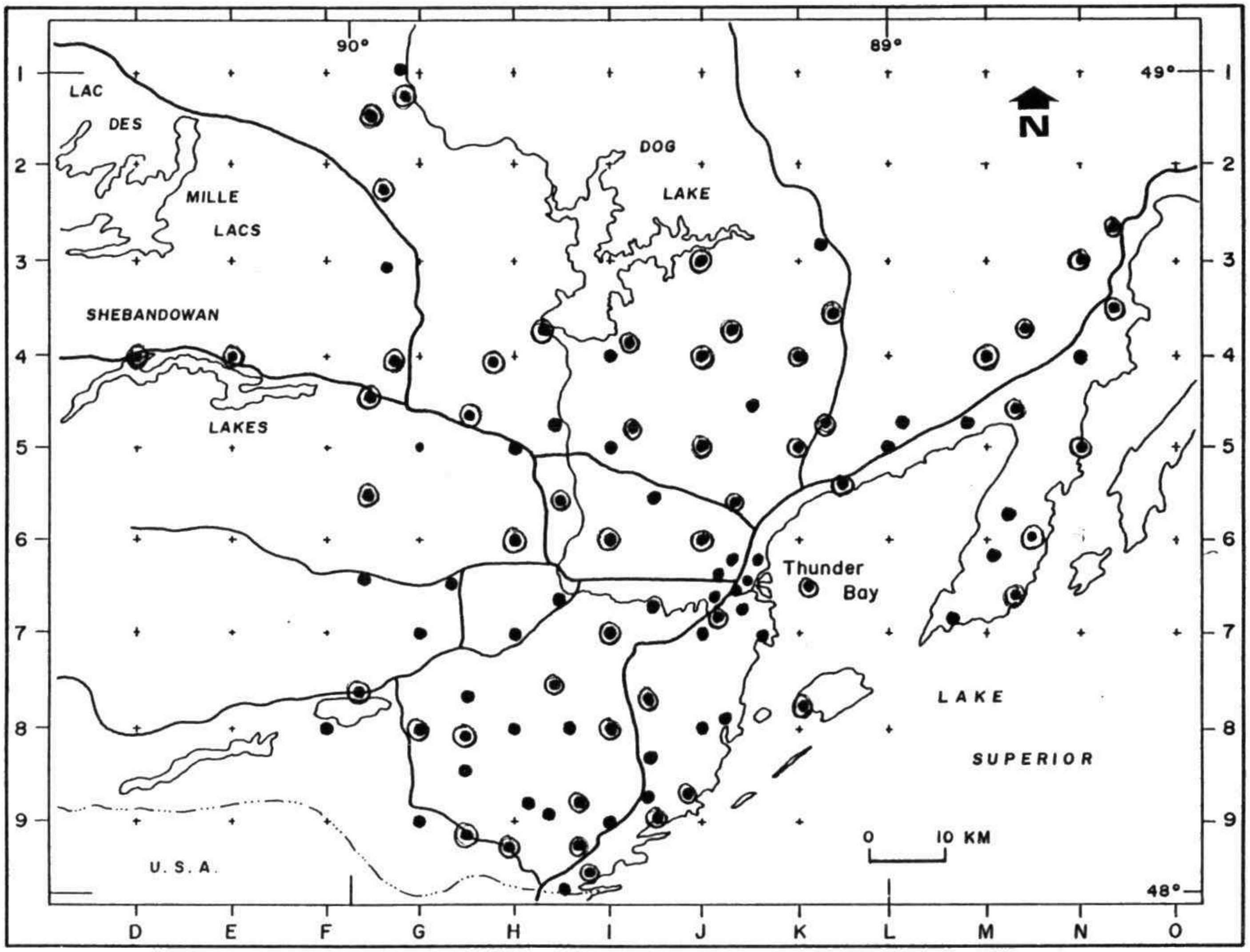
METHODS

METHODS

The field and laboratory methods used in this study have been described in previous reports (Barclay 1981, and 1984). The following methods section presents a rather detailed summary of these methods, but the previous reports can also be used for reference. In order that methods would not be a variable factor, the methods used in the 1981-83 studies are, as nearly as possible, those used in 1970-71.

2.1 Site Selection and Site Descriptions

The major purpose of the 1970-71 study was to catalogue ground and epiphyte vegetation. Therefore, the original site selection was based on vegetation suitability. Practical considerations were also important. A systematic sampling system was based on an 8-mile grid (12.9 km) (Map B), but as motor vehicle transport was required, sites were usually located near passable roads. In order that there be as good a representation of the epiphyte flora as possible, each study site contained six sample trees (three conifers and three deciduous). This usually resulted in sites with mixed conifer-deciduous forest stands, often on mesic sites. Large ground vegetation quadrats, 2 x 20 m were located near the epiphyte sample trees. All sites are described in the earlier reports. The sites which are referred to in this report are also described in Appendix A. A marked set of 1:50,000 Canadian Government topographic maps, to be used together with the site



Map B. Diagrammatic map of all sample site locations.
● Sites sampled in 1970. ◉ Sites resampled in 1980-81.

descriptions, has been given to the Ontario Ministry of the Environment in Thunder Bay.

In 1981, 26 of the original 98 1970 study sites were located and re-sampled (MAP D). In 1983, 28 more sites were located and re-sampled (MAP C). Two of the sites, J8 and M5C could not be relocated, however 1970-71 samples were analysed.

2.2 Lichen Samples

2.2.1 Field Methods

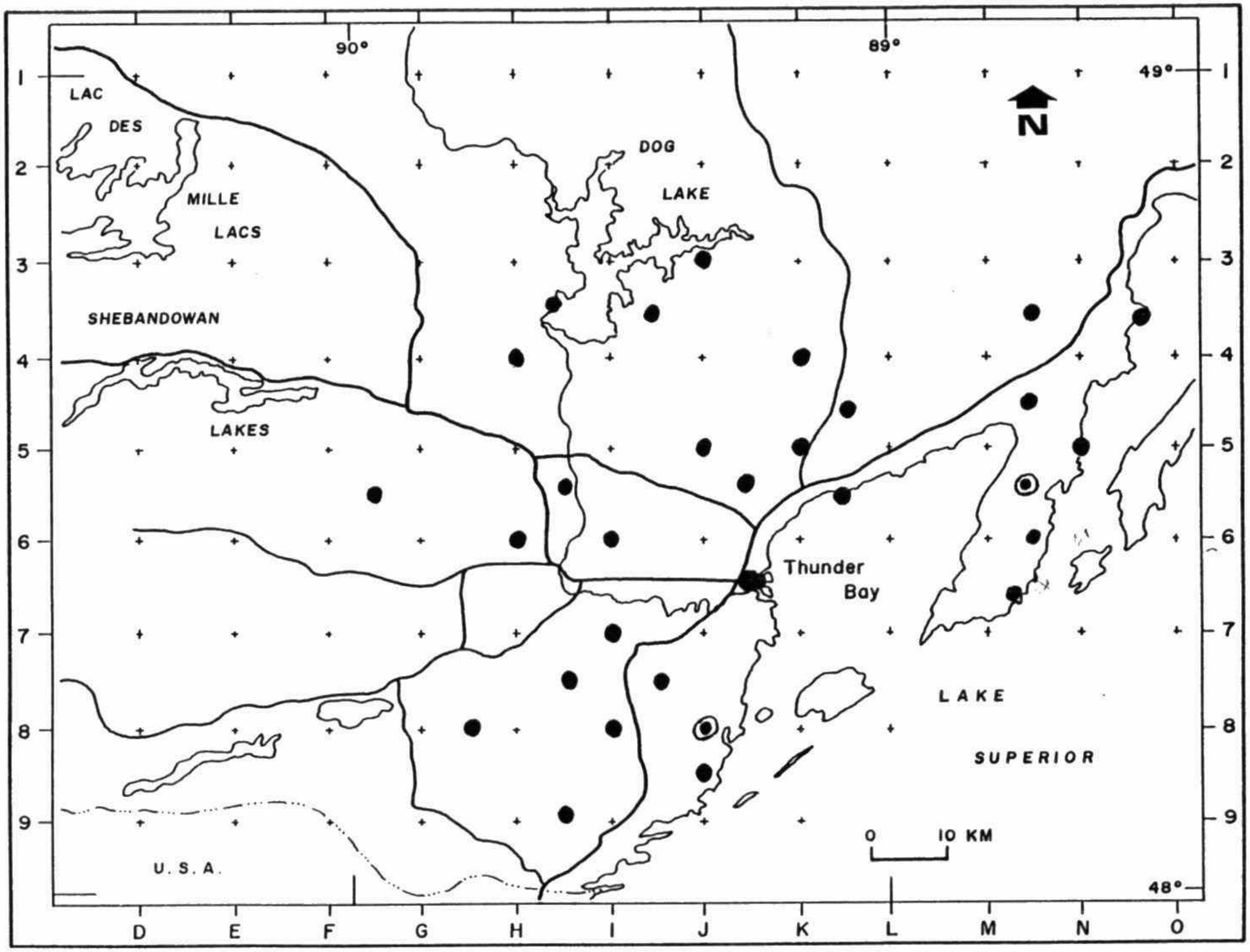
During the 1970-71 study, lichens from 75 sites were sampled for chemical analyses. In 1981, 20 of these sites were re-sampled for lichens and in 1983 an additional 28 sites were re-sampled (Table 1 and Map C). *P. sulcata* was collected from white birch, when present in sufficient quantity. It was collected by hand or scraped from the bark using a Swedish Mora hunting knife. *E. mesomorpha* was collected by hand from balsam fir, where quantities permitted. If suitable rock areas such as outcrops or cliff-talus slopes were nearby, *Umbilicaria* spp. and *C. mitis* s.l. were collected by hand as well. Samples from several trees or ground locations were bulked. Once collected, samples were placed in polyethylene bags, returned to the laboratory and stored in a deep-freeze.

2.2.2 Laboratory Methods

Lichen samples were removed from the deep-freeze and hand-cleaned to remove various types of litter. They were air-dried on aluminum baking trays for 2 - 10 days. The air-dried samples were then ground in a Waring blender and

TABLE 1. Lichen sample sites. C = *Cladina mitis*, E = *Evernia mesomorpha*, P = *Parmelia sulcata*, and U = *Umbilicaria* spp.

SITE NO.	LICHEN sp.				LATITUDE		LONGITUDE		ALTITUDE	DISTANCE TO T.BAY	DATE OF COLLECTION	
	C	U	P	E	Deg.	Min.	Deg.	Min.	(m)	(km)	1970-71	1983
F-5-C	C				48	28	89	57	425	53	12 May 71	2 Sept.
G-8-E			P		48	10	89	48	400	42	26 Aug 70	27 Aug.
H-3-C	C		P		48	42	89	38	440	41	13 May 71	26 May
H-4			P		48	38	89	43	440	44	10 Jul 70	31 Aug.
H-5-C			P	E	48	28	89	37	380	29	4 Jun 70	19 Jul.
H-6			P		48	25	89	47	400	33	1 Jun 70	30 Aug.
H-7-C	C				48	14	89	37	410	29	2 Jun 70	28 Aug.
H-9-E	C	U			48	03	89	34	380	32	21 Aug 70	16 Jul.
I-3-C			P		48	40	89	29	425	31	25 Jun 70	19 July.
I-6			P	E	48	25	89	32	305	21	13 May 70	30 Aug.
I-7			P	E	48	18	89	31	305	20	19 May 70	24 July
I-7-C	C	U	P		48	14	89	27	290	19	28 May 70	16, 24 July
I-8	C			E	48	11	89	34	335	30	27 May 70	24 July
J-3			P		48	45	89	24	440	36	25 Jun 70	11 July
J-5				E	48	32	89	21	410	15	13 May 70	30 Aug.
J-5-C	C				48	26	89	18	290	6	11 Aug 70	26 May
J-6-C		U			48	20	89	17	275	4	2 Jul 70	6 Sept.
J-8			P		48	11	89	19	213	20	27 May 70	--
J-8-S	C	U			48	06	89	21	215	29	13 Aug 70	2 Sept.
K-4			P		48	27	89	11	410	20	8 Jul 70	31 Aug.
K-4-C	C	U	P		48	34	89	06	440	16	12 Jun 70	31 May
K-5	C		P		48	32	89	11	380	8	12 Jun 70	31 May
K-5-C			P		48	30	89	02	190	13	6 May 71	3 Sept.
M-3-C	C		P		48	41	88	43	425	45	15 May 71	26 Aug.
M-4-C	C	U	P		48	34	88	45	215	37	22 Jun 70	26 Aug.
M-5-C	C		P		48	28	88	45	244	33	19 Jun 70	--
M-6-C	C	U	P		48	20	88	46	200	34	25 Aug 70	14 Jul. 26 Aug.
N-3-C		U			48	42	88	35	230	54	15 May 71	26 Aug.
N-5	C		P		48	31	88	38	200	42	19 Jun 70	14 Jul. 26 Aug.
N-6			P		48	25	88	46	245	34	18 Jun 70	14 Jul.
	15+8+21+5 = 49										30 Sites 49 Samples	28 Sites 46 Samples



Map C. Diagrammatic map of Lichen sample sites. Sites J-8 and M-5-C were sampled only in 1970-71(⊙).

sieved through a # 60 mesh sieve. In the case of the 1970-71 material, the sieved samples were returned to polyethylene bags, labelled, and stored in cardboard boxes until analysis in 1983. The sieved 1981 and 1983 samples were put in glass containers in preparation for analysis.

All lichen samples were sent for analysis to the Ontario Ministry of the Environment's Laboratory Services Branch at Rexdale, Ontario. Tests were made for the following elements: Al, As, B, Ca, Cu, Cd, Cl, Cr, F, Fe, Hg, K, Mg, Mn, Mo, N, Na, Ni, P, Pb, S, Zn. For details of these analyses the APIOS Terrestrial Effects Procedures Manual (Griffin, 1983) should be consulted.

The first sets of samples, 28 from the 1970-71 study and 23 from the 1981 study were sent to Toronto and were lost (see also Barclay, 1984). All the analyses are therefore based on 49 remaining 1970-71 samples and 46 new 1983 samples. These samples were taken from 28 sites. A list of these sites and information about each site is given in Table 1. The eight-mile grid location of the lichen sites is shown in Map C.

2.3 Bark Samples

2.3.1 Field Methods

During the 1970 and 1971 field seasons, bark samples were taken on all the 98 study sites. Four samples were taken from each site, usually from two softwood and two hardwood tree species. More than one tree of each species was sampled at the one metre to the two metre level. If epiphytes were present, these were removed. Samples were taken with a Swedish Mora hunting knife, or particularly in the case of white birch and black spruce, by hand. Of the samples collected in 1970-71, 91 have been used in this present study (see Table 2 and Appendix A for details). Once the bark samples were collected, they were placed in polyethylene bags, taken to the laboratory and placed in a deep-freeze for storage. In 1981, 26 of the original sites were located (Table 2 and Map D) and bark samples taken as in 1970-71. All procedures were the same as those used in the earlier study. One hundred and three bark samples were obtained for analysis in 1981.

2.3.2 Laboratory Methods

When processing was to take place, the samples were removed from the freezer and air-dried in the open polyethylene bags. All samples were then ground in a blender (soft bark in 1970-71) or a Wiley Mill (hard bark in 1970-71 and all samples in 1981). The samples were then shipped to the Ministry's Laboratory Services Branch at Rexdale. (For pH and other analyses carried out by Lakehead University during the 1970's, see Barclay, 1981). The samples were analyzed at Rexdale for the same 22 elements as the lichen material, and using the same procedures (Griffin, 1983).

TABLE 2. Bark sample sites. Sw = white spruce. Sb = black spruce. Pj = jack pine. Pw = white pine. Bf = balsam fir. L = tamarack. Ce = white cedar. Bw = white birch. Po = trembling aspen. Pb = balsam poplar. Ab = black ash.

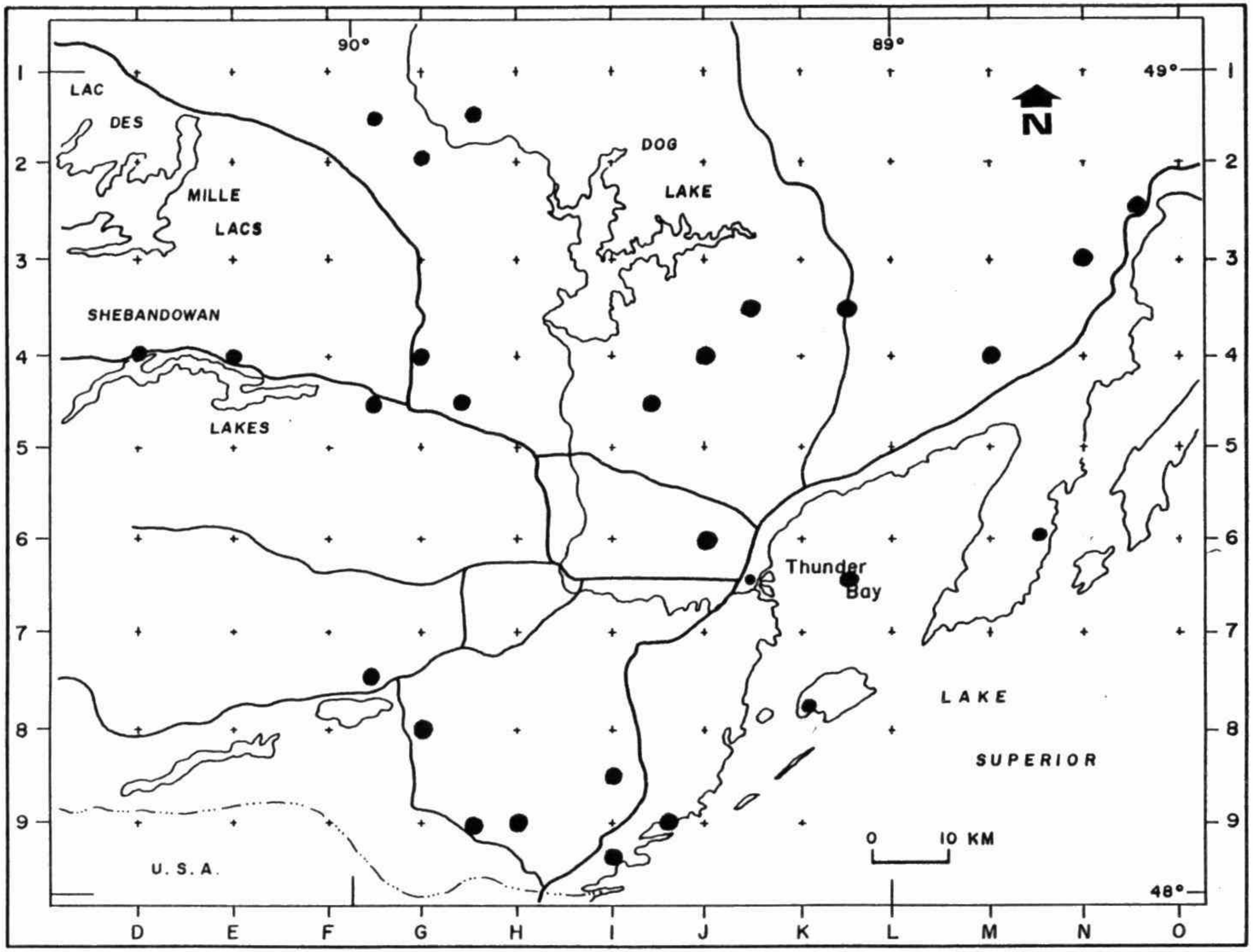
Site No.	Sw	Sb	Pj	Pw	Bf	L	Ce	Bw	Po	Pb	Ab	Longitude 48° Min.	Latitude Deg.	Latitude Min.	Altitude m	Distance to T.Bay km	Date of Collections 1970-71	Date of Collections 1981
D-4	X		X					X	X			40	90	21	475	87.0	27 Aug 70	10 Jun
E-4	X	X						X	X			38	90	12	475	74.1	27 Aug 70	3 Jul
F-1-C	X		X					X	X			55	89	58	475	76.9	1 Jul 70	14 Jul
F-4-C	X		X					X	X			36	89	58	440	58.4	28 May 71	3 Jul
F-7-C	X		X						X	X		14	89	58	410	54.0	27 May 71	8 Jul
G-1-C	X	X	X					X				57	89	53	460	74.7	30 Jun 70	11 Jun
G-2		X	X						X	X		50	89	56	460	68.8	1 Jul 70	11 Jun
G-4		X	X						X	X[2]		39	89	54	410	55.1	29 Jun 70	3 Jul
G-4-C		X	X						X	X		35	89	46	410	45.4	29 Jun 70	13 May
G-8	X		X					X[1]		X		11	89	54	440	50.5	15 Jun 70	8 Jul
G-9-E	X			X					X	X		04	89	47	350	50.4	24 Aug 70	16 Jul
H-9	X			X				X		X		03	89	42	350	47.4	26 May 70	6 May
I-4-C	X		X						X	X		34	89	28	400	24.3	26 Jun 70	13 May
I-8-S	X							X		X	X	07	89	34	350	35.9	26 Aug 70	17 Jun
I-9-S		X		X				X	X			01	89	32	190	42.6	21 Aug 70	29 Jun
I-9-E			X					X	X			05	89	25	200	32.8	13 Aug 70	29 Jun
J-3-C	X	X						X	X			40	89	16	475	25.9	13 May 71	15 May
J-4	X		X					X	X			40	89	21	440	26.7	24 Jun 70	15 Jul
J-6					X	X		X			X	25	89	22	260	6.7	14 May 70	12 May
K-3-C		X	X					X	X			42	89	06	440	29.0	17 Jun 70	19 May
K-6-C	X	X					X	X	X			22	89	07	200	9.9	18 Aug 71	22 May
K-8	X						X	X	X			13	89	09	190	18.4	18 Aug 71	22 May
M-4		X				X		X		X		37	88	45	305	38.6	6 May 71	30 Jun
N-2-C	X	X						X		X		49	88	34	230	62.6	23 Jun 70	25 Jun
N-3		X	X					X			X	47	88	40	410	55.1	23 Jun 70	26 Jun
N-6	X			X					X			25	88	45	245	33.5	18 Jun 70	19 Jun
Totals 26																		

17+11+ 14 + 4 + 1 +2 + 2 + 17+18 + 10+ 3 = 99 1970 - 71 Samples

17+12+ 14 + 4 + 1 +2 + 2 + 19+18 + 10+ 3 =102 1981 Samples

1 = No sample in 1970-71

2 = No sample in 1981



Map D. Diagrammatic map of Bark sample sites. Sampled in 1981.

A test for pH was added, using water as the solvent (Griffin, 1983).

2.4 Statistical Analyses

Some preliminary statistics were done, using a Macintosh Plus personal computer and a programme titled STATVIEW. Most analyses, however, have been done on the Lakehead University VAX 11/780 computer using the SPSS (Nie *et al*., 1975) statistical procedures. All data have been included, anomalous amounts have not been excluded from the statistics.

RESULTS

3.0 RESULTS

The results of the field and laboratory studies are presented in the same order as the topics in the "Methods" section, with lichen information presented first, followed by the bark information. Tables are presented sequentially at the end of this section.

The major objective of this study is to compare the 1970 samples with those from the 1980's. Comparisons are made between these years sample sets, using various groups of data. Data groups may be chemical elements, lichen species or groups of lichen species. Sites are arranged in the tables according to increasing distance from Thunder Bay city.

3.1 Lichen Samples

In the lichen species, heavy metal analyses, plus Al and As, are shown in Tables 3 and 5. These results are quite consistent in that most elements in the sample groups from the four lichen species show a decrease from 1970 to 1983. In *C. mitis* all elements, except Ni, decrease an average of 43%, with Hg, Pb and As showing particularly large decreases. The *Umbilicaria* spp. samples also show most elements decreasing in the 13-year period. Cr, Fe, Hg, Ni, Pb, Al, and As all decrease, with Pb and As having the largest decreases; Cd and Zn increase by about 20%, and Mn has a large increase of over 50%. Cu is the same in the 1970 and 1983 sample sets. Mo also increases but there are too few data for this to be taken into consideration. In the larger *P. sulcata* data set, all elements decrease except Mn, which has a rather small increase. The average decrease is 46%, with Cr, Fe, Ni, Pb, Al, and As exceeding even this large average decrease. The small *E. mesomorpha* data set has eight elements (Cu, Cd, Cr, Fe, Mn, Ni, Zn, and Al) increasing by an average of 33% and only three elements (Hg, Pb, and As) decreasing.

Tables 4 and 5 present all the lichen analysis data for the plant nutrient elements (fluoride is also included). In *C. mitis* all the elements are present in smaller quantities in the 1983 samples than in the 1970 samples. The average reduction is about 27%. *Umbilicaria* spp., however, shows all elements to increase in 1983 by about 19% except Na which decreases by 0.4%. The results for *P. sulcata* are mixed in that four elements, Ca, K, Cl, and S increase by an average of 25%, (F also increases but these are too few data to give this increase any significance). Five elements, Mg, Na, B, N, and P decrease by an average of 23%. In the small sample group of *E. mesomorpha*, all elements increase an average of 45%.

All the sites that have paired 1970 and 1983 samples are used in Table 5 for Students *t* significance tests. The *C. mitis* and *P. sulcata* data sets show significant differences for most of the elements. The smaller *Umbilicaria* spp.

and *E. mesomorpha* sets have in most cases no significant differences between elements of the 1970 and 1983 data sets. In all there are 29 cases where significant differences are indicated. There are significant decreases in 27 of these cases ($p \leq 0.05$). Only in B in *E. mesomorpha* and in Cl in *P. sulcata* are there significant increases, and both are at the $p = 0.05$ level of significance. In particular, Hg and Al are very significantly decreased ($p = 0.001$) from 1970 to 1983 in both *C. mitis* and *P. sulcata*. Pb decreases significantly in three species ($p = 0.05$ in *Umbilicaria* spp., $p = 0.01$ in *P. sulcata*, and $p = 0.001$ in *C. mitis*). As is very significantly decreased in all four species (*Umbilicaria* spp. and *E. mesomorpha* $p = 0.01$, and *C. mitis* and *P. sulcata* $p = 0.001$). When all paired data for all species are combined, Al and the heavy metals As, Cr, Fe, Hg, and Pb are significantly decreased ($p \leq 0.01$).

Tables 6 to 10 are matrices of significance levels, based on Pearson correlation coefficients for paired sets of data. Besides comparisons of elements and sample years, correlations are also made between sample sites and distance to Thunder Bay city, distance to Lake Superior, and altitude. Table 6 shows significance levels of *C. mitis*. This ground lichen has 9 elements (Al, As, Cd, Fe, Ca, Mg, Na, N, and S) that are significantly negatively correlated with distance of the sites from Thunder Bay (i.e., the larger the distance from the city the smaller the amounts of these elements). In all cases, these negative correlations are made with the 1983 data sets. Cr is positiviely correlated with distance both in 1970 and in 1983, and Ni is also positively correlated in the 1970 samples. There are two positive 1983 correlations to distance from Lake Superior (K and S) and none with altitude. Of the 22 elements, only six (Mn, P, Hg, K, Pb, and S) have positive correlations between the 1970 and 1983 sample sets, and all at the lower $p = 0.05$ significance level. Virtually all the other correlations are positive and tend to be within sample years (i.e., 1970 to 1970), but not between sample years (i.e., 1970 to 1983). While there is a tendency for heavy metals to correlate with heavy metals, and for nutrient elements to correlate with nutrient elements, there are no strong, clear sets of relationships. The *Umbilicaria* spp. correlations are shown in Table 7. In this rock lichen there are five elements (P, N, B, Mo, and Zn) correlated with distance from Thunder Bay. Unlike in *C. mitis*, these distance correlations are all positive. In the *Umbilicaria* spp. correlations between 1970 and 1983 data sets only Hg and Na are positively correlated and Al is negatively correlated. There are a number of other negative correlations in this matrix, with a rather random distribution within the matrix. These negative correlations tend to be weaker at the $p = 0.05$ significance level. As with *C. mitis*, the *Umbilicaria* spp. correlations tend to be within sample year correlations and not between sample years. Other relationships are problematical. The *P. sulcata* matrix (Table 8) shows six elements (Fe, B, Cr, K, Na, and Zn) to be correlated with distance from Thunder Bay. Three of these (Fe, Cr, and Na) are negatively correlated and three (B, K, and Zn) are positively correlated. Nine elements (N, P, K, S, As, Cu, Hg, Ni, and Pb) are negatively correlated with distance from Lake Superior, and nine elements (N, Cl, S, Fe, Cr, Cu, Ni, Pb, and Zn) are negatively correlated with altitude. Mn is positively correlated with altitude. Only Na and Pb have positive correlations between the 1970 and 1983 data sets. Again in this *P. sulcata* matrix, as was the case with *Umbilicaria* spp., there is a rather random distribution of weak correlations in the matrix. Also, again, there is a tendency for the stronger positive correlations to occur between elements of the same years data sets. Table 9 for the *E. mesomorpha* samples correlations shows several elements (Fe, Mn, Ca, Cr, Mg, Na, and Ni) to be negatively correlated with distance from Thunder Bay. Two elements P and As are positively correlated with distance from Thunder Bay. Generally, the *E. mesomorpha* matrix has a rather random distribution of both negative and positive associations, mostly at the $p = 0.05$ significance level. The final correlation matrix is for all lichen samples combined and is shown in Table 10. This table shows Fe, Al, As, Cr, Hg, Mg, and Na to be negatively correlated with distance from Thunder Bay and one element, Mo, to be positively correlated to this parameter. There are few relationships indicated between the distribution of the 22 elements and distance from Lake Superior or altitude. The rest of the matrix has a large number of positive correlations, mostly at the very significant p = 0.001 level, with frequent interrelationships between heavy metals and all the other elements. There are conspicuously few correlations between F and any other elements between Mo and any other elements, and between the 1983 Ni sample set and any other sample groups.

3.2 Bark Samples

The bark sample pH values are given in two tables, conifer bark values in Table 11 and deciduous bark values in Table 12. All the 1970 and 1981 conifer bark pH means are very acid. There is a tendency for the arithmetic pH means to be higher in 1981 than in 1970 in all tree species, except for the small white cedar sample. The pH value increases are small, but when the hydrogen ion concentration at these low pH's is taken into account, these changes are substantial. In all cases, the pH values from the Ministry analyses are more acid than the results obtained at Lakehead University in 1981 (see Barclay 1981 for details). Table 12 presents the deciduous tree bark pH values. There is again a tendency for pH values to be higher in 1981 than in 1970. However, as these species have bark pH in the higher part of the scale, the hydrogen ion amounts are less than the amounts for the conifer bark. Also, as in the conifer bark samples, the Lakehead University bark pH's are higher than those obtained by the Ministry.

All heavy metal, Al, and As analayses for conifer bark samples are presented in Table 13. The white spruce samples show four of the elements increasing during the eleven years and six elements decreasing. Hg and As have large decreases. Fe and Ni have large increases. In black spruce, three elements increase but seven elements decrease; of these seven there are large decreases in Fe, Hg, Al and As. Eight of the 12 metals decrease in the jack pine bark samples. Fe and Hg show particularly large decreases. The small white pine sample set shows two large decreases, Hg and Mn, and one very large increase in Pb (owing to one anomalously high value). The other conifer bark data sets (balsam fir, tamarack, and white cedar) are too small for interpretation.

The deciduous tree bark analyses for heavy metal and Al and As are presented in Table 14. The white birch bark shows large decreases in Hg and As and a large increase in Cd. The trembling aspen bark also shows a large decrease from 1970 to 1981 in Hg and As. Balsam poplar bark analyses have all metals decreasing, except Pb which is unchanged and large decreases during the 11-year period in Cr, Fe, Hg, Al, and As. The small black ash sample has all elements decreasing except Pb, with large decreases in Cr, Al, and As.

Table 15 presents nutrient element analyses for the conifer bark samples. In white spruce bark, half of the elements (K, F, N, P, and S) show moderate decreases and no large increases from 1970 to 1981. In the black spruce bark, most elements decrease, with K and S having moderately large decreases. A rather similar pattern is present in the jack pine bark samples except that there are quite large decreases in both K and S. The white pine, balsam fir, tamarack and white cedar sample sets are too small to show clear trends, but S in particular does show a large decrease. Table 16 shows nutrient elements (plus F) for the deciduous bark samples for 1970 and 1981. The elements Ca, K, Mg, Na, and B do not show any consistent pattern of increase or decrease in the deciduous tree species bark. The Cl analyses are almost all below the detection limit ($<$ 100 ug/g) except in white birch, where the amounts are quite high. Fluoride, too, presents some unusual results. It declines in all conifer species and also in all deciduous species except for white birch. In white birch it increases by 70 percent! N, P, and S uniformly decrease from 1970 to 1981 in the deciduous tree species except white birch where they are unchanged.

Paired *t* tests were made between all 1970 and 1981 bark data sets. Table 17 shows the results for the conifer bark data. Only the black spruce and the jack pine bark samples show very significant differences. In black spruce there are significant decreases ($p = 0.01$) in Fe, Hg, Al, As, and N. Jack pine has significant decreases in Al and N ($p = 0.05$), in Cu, K, and S ($p = 0.01$) and in Hg ($p = 0.001$). While there are some significant decreases, there are no significant increases in any elements in any of the conifer data sets. There are fewer significant differences between the deciduous tree bark data for 1970 and 1981 than in the conifer data (Table 18). In white birch, As is very significantly decreased ($p = 0.001$). In trembling aspen there are significant decreases ($p = 0.05$) in Cu and F. Mg increases significantly ($p = 0.05$) and is the only element that does so. In balsam poplar, F, P, and S decrease significantly from 1970 to 1981 ($p = 0.05$) and so does Hg, but more strongly ($p = 0.01$). When the data from all deciduous species are combined (Table 19) there are significant decreases at the $p = 0.05$ level in P and S, and at the $p = 0.001$ level in As and Hg. Also, in Table 19, data from all the conifer bark samples show more significant decreases; Cu and Al ($p = 0.05$), S ($p = 0.01$), Hg and N ($p = 0.001$). When all the data from all the bark samples are combined, as in Table 19, a number of significant differences are evident and all are decreases. There are significant decreases: ($p = 0.05$) in As; ($p = 0.01$) in Al, N, and P; ($p = 0.001$) in Hg, and S.

A number of matrices have been prepared to show bark sample inter-relationships based on the levels of significance of Pearson correlation coefficients. Besides showing the element relationships, 3 other variables are included in each matrix:distance from Thunder Bay city, distance from the closest place on Lake Superior, and altitude of the site. Table 20 shows the inter-relationships between the 1970 and 1981 white spruce bark sample sets. There are a number of negative correlations between distances from Thunder Bay and from Lake Superior, and also particularly to altitude. Eight elements (Mn, B, Ca, Cd, Cr, Cu, F, Mg) have correlations between the 1970 and the 1981 samples. There are a number of positive correlations between nutrient elements, but fewer metal pair correlations. The black spruce sample correlations in Table 21 show several negative correlations between metal and non-metal elements and distance from Lake Superior and altitude. Only five elements (Mn, Al, Cd, F, and Mg) have positive correlations between the 1970 and the 1981 samples. Most of the negative correlations between elements in this matrix are associated with Fe, Mn, and P. The jack pine bark element interrelationships shown in Table 22 have a number of negative correlations with distance from Thunder Bay, distance from Lake Superior, and altitude. Two elements, Cd and Zn, are strongly linked with these three variables. Nine of the 22 elements (Fe, Mn, Al, As, Cd, F, Na, Ni, and Zn) have significant positive correlations between the 1970 and 1981 sample sets. Mg and K have a negative correlation between the two sets. As in jack pine, in the bark of white birch (Table 23) there is significant negative correlation between Cd and distance and altitude. Eight elements (Fe, N, Al, Cd, Cr, Hg, Mg, and Zn) have positive correlations between the 1970 and 1981 sample sets.

In Table 24, trembling aspen bark, only six elements (As, B, Ca Cr, Hg, and Ni) have between-year correlations (all are positive, except B). In the balsam poplar matrix (Table 25), there are scattered negative correlations between mostly metal elements and distances and altitude. Only three elements (N, P and S) have positive correlations between 1970 and 1981 data sets. Two elements (B and Ca) have negative correlations between these year sets. B and Ca also have a number of negative correlations with other elements.

The last three matrices (Tables 26 to 28) are for combined bark data, which include the three major conifer species, the three major deciduous species and combined data for all tree species. The combined conifer data matrix in Table 26 shows a number of distance-altitude negative correlations, especially for Ca, Cd, Cu, and Zn. Most of the elements show strong positive correlations between 1970 and 1981 data sets (Fe, Mn, Al, As, B, Ca, Cd, Cr, Cu, F, K, Mg, Ni, and Zn). There is a marked absence of correlations between Mo and any other elements. Nutrients elements tend to be inter-correlated, but Al tends to be negatively correlated with the nutrient elements. The heavy metals Hg and Pb have relatively few strong correlations. The combined deciduous tree bark data in Table 27 have fewer distance-altitude relationships than has the conifer bark data, with Cd and Cr being exceptions. There are 14 elements (Mn, P, As, B, Ca, Cd, Cl, Cr, Hg, K, Mg, Ni, S, and Zn) with positive correlations between 1970 and 1981 data sets but the relationships are not as strong as in the conifer bark. Mo has few correlations, as in the conifer bark, but Cl has a number of strong, mostly negative, correlations. Mn also has strong negative correlations with elements such as B, Ca, Cd, K, Mg, and S. Nutrient elements tend to be inter-correlated but this is less so in the metal elements. The combined data for all bark samples (Table 28) has several strong negative correlations between distance and altitude, especially for Cd, Cr, Ni, and Pb. Most of the elements have strong ($p = 0.001$) positive correlations between the 1970 and 1981 data sets; only F, Mo, and Na do not. Mn, Cl, and Hg have negative correlations with several other elements. The strongest positive correlations, though, are between nutrient elements. In the metals, Cu, Cd, and Zn also show positive correlation with several elements, but Mo is again lacking correlation pairs.

RESULTS TABLES

TABLE: 3 Lichen heavy metal analyses for 1970 and 1983 (10 heavy metals, plus Al and the Metalloid As). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below detection limit. Detection limits in micrograms/gram: Cr<1.0, Mo<0.5, Ni<1.0.

CLADINA MITIS:

SITE	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-5-C	9	5	0.5	0.3	2	2	2000	1500	0.10	0.04	48	35	b.d.	b.d.	3	2	43	13	40	24	1200	840	2.73	0.89
K-5	7	8	0.4	0.3	2	4	1200	1900	0.06	0.05	100	98	b.d.	b.d.	2	3	31	13	39	23	900	1200	1.84	1.62
K-4-C	6	4	0.4	0.3	2	2	1400	1300	0.05	0.03	23	35	b.d.	b.d.	2	2	43	15	32	15	1000	990	1.57	0.72
I-7-C	6	9	0.5	0.4	2	3	2800	1900	0.11	0.05	29	36	b.d.	b.d.	2	2	33	16	34	24	1400	1300	2.66	0.89
H-7-C	6	7	0.4	0.4	3	2	1700	1300	0.10	0.05	71	32	b.d.	b.d.	2	2	21	12	33	23	1300	850	2.11	1.07
J-8-S	7	3	0.6	0.3	3	1	1700	620	0.07	0.02	110	26	b.d.	b.d.	3	b.d.	47	13	57	19	1200	440	2.11	0.54
I-8	4	4	0.4	0.2	2	1	1700	1300	0.07	0.02	38	21	b.d.	b.d.	2	9	21	10	29	17	1100	810	2.11	0.72
H-9-E	7	7	0.6	0.3	3	1	1700	900	0.09	0.04	59	31	b.d.	b.d.	3	27	43	13	49	22	1200	820	2.64	0.72
M-5-C	7		0.5		3		1900		0.10		86		b.d.		4		55		40		1600		2.53	
M-6-C	7	10	0.4	0.3	2	1	1100	500	0.12	0.03	50	18	b.d.	b.d.	2	b.d.	34	10	34	13	940	430	1.93	0.63
M-4-C	7	8	1	0.3	6	2	1400	980	0.10	0.04	140	63	b.d.	b.d.	5	2	40	20	51	20	1100	650	2.02	0.80
H-3-C	8	4	0.3	0.2	2	2	1000	730	0.06	0.03	22	29	b.d.	b.d.	2	b.d.	24	11	25	15	940	610	1.43	0.54
N-5	3	4	0.4	0.2	2	1	920	830	0.05	0.03	50	68	b.d.	b.d.	5	1	42	16	31	19	780	710	1.66	0.72
M-3-C	12	5	1	0.3	4	2	2100	830	0.15	0.05	120	82	0.6	b.d.	4	1	72	17	59	26	2100	660	2.95	0.72
F-5-C	9	6	0.6	0.2	7	2	2300	880	0.06	0.03	62	22	b.d.	b.d.	6	1	36	12	42	12	1600	590	2.45	0.63
$\bar{x}$	7	6	0.5	0.3	3	1.9	1661.3	1105	0.09	0.04	67.2	42.6			3.1	3.7	39	13.6	39.7	19.4	1224	778.6	2.18	0.80
S.D.	2.1	2.2	0.2	0.1	1.6	0.9	515.9	441.6	0.03	0.01	36.6	24.9			1.4	7.1	13.3	2.8	10.2	4.5	341.5	254.4	0.46	0.28

TABLE: 3 Cont. Lichen heavy metal analyses for 1970 and 1983 (10 heavy metals, plus Al and the Metalloid As). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below detection limit. Detection limits in micrograms/gram: Cr<1.0, Mo<0.5, Ni<1.0.

UMBILICARIA:

SITE	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-5-C	16	13	0.6	0.8	6	5	5800	6700	0.45	0.28	30	33	b.d.	0.6	7	7	77	49	50	39	1800	1900	5.40	3.02
K-4-C	10	6	0.5	0.3	7	1	3200	870	0.19	0.10	27	14	b.d.	b.d.	5	1	100	22	45	33	2100	750	3.63	2.17
I-7-C	9	23	0.4	1.8	2	8	1800	5400	0.20	0.20	25	150	b.d.	b.d.	2	10	50	37	44	110	1100	4300	3.73	3.59
J-8-S	8	11	0.4	0.4	3	3	2100	2400	0.15	0.14	22	31	b.d.	0.7	3	2	70	46	50	43	1400	1600	3.14	2.17
H-9-E	19	10	0.9	0.5	4	6	4500	1700	0.24	0.12	46	23	b.d.	b.d.	6	4	130	33	64	29	2800	1300	4.28	1.43
M-6-C	6	4	0.3	0.2	5	b.d.	3900	190	0.20	0.19	42	15	b.d.	b.d.	5	b.d.	20	8	73	150	4800	240	2.02	1.89
M-4-C	8	10	0.6	0.5	0.6	5	3600	3500	0.23	0.22	73	150	b.d.	b.d.	4	5	58	32	64	74	2400	3100	4.23	2.45
N-3-C	12	11	0.7	0.8	3	4	2500	2000	0.23	0.24	49	62	0.5	0.6	4	4	120	87	90	100	2000	1800	4.86	2.45
$\bar{x}$	11	11	0.6	0.7	4.5	4	3425	2845	0.24	0.19	39.3	59.8			4.5	4.1	78.1	39.3	60	72.3	2300	1873.8	3.91	2.40
S.D.	4.4	5.7	0.2	0.5	1.8	2.6	1328.5	2235.8	0.09	0.06	17.0	57.7			1.6	3.3	37.0	23.3	16.0	44.1	1142.7	1294.6	1.05	0.67

TABLE: Lichen heavy metal analyses for 1970 and 1983 (10 heavy metals, plus Al and the Metalloid As). Units are micrograms per gram. The sample sites are arranged in
3 order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is
Cont. below detection limit. Detection limits in micrograms/gram: Cr<1.0, Mo<0.5, Ni<1.0.

PARMELIA SULCATA:

SITE	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		A1		As	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
K-5	28	13	1.2	0.8	11	4	7700	2100	0.40	0.11	330	330	b.d.	b.d.	10	5	73	32	100	110	4000	1500	5.74	2.02
K-5-C	27	21	1.2	0.8	8	6	6400	3300	0.36	0.21	210	290	b.d.	b.d.	9	5	170	98	170	140	3400	2300	6.67	2.54
K-4-C	35	14	1.5	0.7	16	3	9400	1500	0.27	0.22	330	330	b.d.	b.d.	14	3	95	44	130	140	5500	1300	6.08	2.08
I-7-C	19	7	1.3	0.9	5	b.d.	3500	570	0.27	0.08	160	100	b.d.	b.d.	5	2	61	29	250	130	2700	510	5.29	1.52
K-4	17	14	0.7	0.6	4	4	3100	2200	0.25	0.17	69	180	b.d.	b.d.	4	4	73	58	120	150	2600	2000	5.18	2.26
I-7	19	9	1.3	1.4	4	5	4200	2200	0.29	0.15	160	200	b.d.	b.d.	5	3	76	38	190	160	2500	1300	6.13	4.58
J-8	21		0.8		5		2100		0.35		190		1.3		4		47		140		1700		5.29	
I-6	22	11	1.1	0.7	0.7	3	6800	2300	0.27	0.11	100	200	b.d.	b.d.	7	3	76	27	210	140	3000	1200	5.50	3.01
H-5-C		12		0.9		4		2600		0.16		300		b.d.		4		48		150		1800		2.45
I-8	23		2.4		4		3400		0.20		45		b.d.		4		56		190		2800		5.19	
I-3-C		10		0.9		3		1300		0.14		350		b.d.		3		28		140		1300		2.56
H-6		20		0.9		9		5200		0.23		150		b.d.		23		51		160		3000		3.69
M-5-C	11		0.9		4		2000		0.29		550		0.5		5		34		160		1800		5.18	
N-6		13		0.8		3		1600		0.21		310		b.d.		4		35		160		1300		2.82
M-6-C		9		0.8		3		670		0.12		190		b.d.		2		29		120		590		2.26
J-3	20	9	1.1	0.6	0.7	2	3800	790	0.20	0.12	460	520	b.d.	b.d.	8	2	55	21	160	170	2700	760	3.69	2.64
M-4-C	20	35	1.1	1.3	5	5	3700	2600	0.25	0.27	160	110	b.d.	b.d.	6	5	77	57	290	170	2700	1600	5.08	3.21
H-3-C		9		0.4		2		860		0.06		520		b.d.		2		22		190		850		2.45
G-8-E	26	7	1.8	1.0	7	1	6600	700	0.34	0.09	620	200	b.d.	b.d.	9	2	56	26	220	240	3800	650	6.67	1.89
N-5		6		0.6		2		1100		0.08		350		b.d.		2		29		130		1100		2.73
H-4	18	13	1.0	0.7	3	3	1900	1700	0.17	0.15	330	260	b.d.	b.d.	4	3	51	37	220	170	1900	1400	3.89	2.26
M-3-C	18	9	1.2	1.1	5	2	3500	950	0.32	0.10	150	420	b.d.	b.d.	6	2	100	33	130	200	2900	870	7.16	2.82
$\bar{x}$	21.6	12.7	1.2	0.8	6.3	3.4	4540	1802.1	0.28	0.15	257.6	279.5			6.7	4.2	73.5	39.1	178.7	156.3	2933.3	1333.2	5.60	2.62
S.D.	5.7	6.7	0.4	0.2	3.4	2.0	2278.7	1136.7	0.06	0.06	174.5	121.8			2.9	4.7	32.0	18.1	52.6	30.4	965.6	624.9	1.0	0.68

TABLE: Lichen heavy metal analyses for 1970 and 1983 (10 heavy metals, plus Al and the Metalloid As). Units are micrograms per gram. The sample sites are arranged in
3 order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is
Cont. below detection limit. Detection limits in micrograms/gram: Cr<1.0, Mo<0.5, Ni<1.0.

EVERNIA MESOMORPHA:

SITE	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		A1		As	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-5	12	16	0.4	0.6	3	7	2000	5200	0.46	0.46	29	65	b.d.	b.d.	3	8	30	30	58	53	1200	2700	4.68	3.59
I-7	5	17	0.3	0.9	2	5	1000	3300	0.54	0.38	14	63	b.d.	b.d.	2	4	10	22	27	61	690	1500	5.61	4.58
I-6	14	12	0.6	0.4	6	5	5800	3300	0.66	0.34	41	58	b.d.	b.d.	6	5	33	19	46	56	2200	1400	6.19	2.54
H-5-C	11	11	0.5	0.5	4	4	2300	2100	0.51	0.43	61	48	b.d.	b.d.	3	3	43	31	50	45	1300	1200	6.55	2.54
I-8	20		0.6		4		3300		0.77		30		b.d.		4		31		70		2200		7.55	
$\bar{x}$	12.4	14	0.5	0.6	3.8	5.3	2880	3475	0.59	0.40	35	58.5			3.6	5	29.4	25.5	50.2	53.8	1518	1700	6.12	3.31
S.D.	5.4	2.9	0.1	0.2	1.5	1.3	1826.7	1281.6	0.13	0.05	17.4	7.6			1.5	2.2	12.0	5.9	15.9	6.7	664.2	678.2	1.07	0.98

TABLE: 4 Lichen non-metal analyses for 1970 and 1983 (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below detection limit. Detection limits in micrograms/gram: B<1.0, C1<100.0, F<1.0.

CLADINA MITIS:

SITE	Ca		K		Mg		Na		B		C1		F		N		P		S	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-5-C	1400	1100	2000	1800	550	470	73	74	5	2	b.d.	b.d.	b.d.	b.d.	8900	5900	700	500	700	500
K-5	1800	1600	1900	1900	460	680	43	100	3	5	b.d.	b.d.	b.d.	b.d.	5800	5700	600	600	500	300
K-4-C	710	640	1500	1300	420	340	51	53	3	b.d.	b.d.	b.d.	b.d.	b.d.	4600	4200	400	400	300	300
I-7-C	790	790	1900	1700	520	450	46	52	4	4	b.d.	b.d.	b.d.	b.d.	4800	4700	500	300	400	300
H-7-C	1100	880	1900	1600	440	340	38	43	4	4	b.d.	b.d.	b.d.	b.d.	4800	4500	600	500	300	300
J-8-S	2400	720	1600	1200	450	240	36	29	7	3	b.d.	b.d.	b.d.	b.d.	7000	4000	600	300	500	300
I-8	1200	860	1700	1200	600	390	44	40	3	5	b.d.	b.d.	b.d.	b.d.	5100	3900	500	400	300	100
H-9-E	2000	780	2200	2000	690	370	55	50	5	3	b.d.	b.d.	b.d.	b.d.	8100	4800	1000	600	600	300
M-5-C	890		1900		440		64		3		b.d.		b.d.		6000		500		500	
M-6-C	1800	900	2300	1500	550	320	92	29	3	3	b.d.	b.d.	b.d.	b.d.	9400	4200	700	400	700	300
M-4-C	1500	880	2200	1500	550	300	32	32	6	4	b.d.	b.d.	b.d.	b.d.	7800	5000	700	500	600	300
H-3-C	800	720	1200	1200	380	280	50	38	3	3	b.d.	b.d.	b.d.	b.d.	4700	4200	300	400	300	200
N-5	600	720	1800	1600	360	380	34	26	3	4	b.d.	b.d.	b.d.	b.d.	4600	3900	500	300	200	300
M-3-C	1300	930	2000	1600	520	320	57	33	7	4	100	b.d.	b.d.	b.d.	7000	5400	500	400	700	400
F-5-C	1400	570	1900	1000	710	280	89	39	5	3	b.d.	b.d.	b.d.	b.d.	7200	3800	600	300	500	100
$\bar{x}$	1312.7	863.6	1867	1507	509.3	368.6	53.6	45.6	4.3	3.4					6387	4586	580	421	473	286
S.D.	522.6	250.4	285	295	103.1	110.2	18.7	20.2	1.5	1.3					1651	692	161	105	167	103

TABLE: Lichen non-metal analyses for 1970 and 1983 (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged
4 in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below
Cont. detection limit. Detection limits in micrograms/gram: B<1.0, C1<100.0, F<1.0.

UMBILICARIA SP.:

SITE	Ca		K		Mg		Na		B		C1		F		N		P		S	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-6-C	240	610	2900	2700	370	390	130	140	6	6	b.d.	b.d.	b.d.	b.d.	7100	8100	500	800	1100	1000
K-4-C	420	270	3200	3200	530	430	72	56	4	3	b.d.	b.d.	b.d.	b.d.	12700	12000	1100	700	1200	1400
I-7-C	510	3500	2200	4500	340	1400	43	71	4	13	b.d.	b.d.	b.d.	b.d.	9600	16700	700	1600	1000	2300
J-8-S	340	590	2500	2800	320	420	42	46	5	7	b.d.	b.d.	b.d.	b.d.	9500	9900	600	900	1200	1100
H-9-E	610	430	3100	3300	630	430	100	77	8	3	b.d.	b.d.	b.d.	b.d.	10500	10900	1000	1100	1100	1500
M-6-C	3000	770	5000	4600	1000	410	45	25	9	14	b.d.	b.d.	b.d.	b.d.	11800	11000	1000	1100	2200	2100
M-4-C	1100	2000	4100	4600	680	780	58	62	8	9	b.d.	b.d.	b.d.	b.d.	11000	16000	1100	1200	1200	2300
N-3-C	720	1200	4100	4300	600	390	51	61	8	11	b.d.	b.d.	b.d.	b.d.	13500	15000	1800	1400	1600	1900
$\bar{x}$	867.5	1171.3	3387	3750	558.8	581.3	67.6	67.3	6.5	8.3					10710	12450	975	1100	1325	1700
S.D.	901.6	1088.0	939.0	830.0	226.0	355.4	31.9	33.5	2.0	4.2					2028	3101	406.0	302.0	396.0	521.0

TABLE: Lichen non-metal analyses for 1970 and 1983 (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged
4 in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below
Cont. detection limit. Detection limits in micrograms/gram: B<1.0, C1<100.0, F<1.0.

PARMELIA SULCATA:

SITE	Ca		K		Mg		Na		B		C1		F		N		P		S	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
K-5	2100	4700		4500	1300	790	180	100	11	12	b.d.	700	b.d.	b.d.	12700	7600	1400	1300		1300
K-5-C	2100	3100	4000	4200	1000	940	140	110	18	19	900	1100	b.d.	b.d.	15000	13000	1100	1000	1600	1300
K-4-C	2900	5800	4500	3600	2200	640	370	110	16	13	600	1100	b.d.	b.d.	11900	9400	1100	800	1100	1200
I-7-C	2300	4800		4200	990	460	85	26	25	12	b.d.	700	b.d.	b.d.	12100	7600	1600	900		1100
K-4	2600	5000		4800	700	890	76	74	14	18	b.d.	800	b.d.	b.d.	12200	12500	1100	1100		1200
I-7	1200	2900	3600	4900	620	750	74	62	20	19	800	800	b.d.	b.d.	12800	10500	1000	1000	1300	1400
J-8	1100				460		112		16		b.d.		b.d.							
I-6	3300	12000		4300	1100	900	140	79	24	15	b.d.	800	b.d.	3	13000	17500	1000	1300		1100
H-5-C		2700		4200		1000		78		17		800		b.d.		8100		1100		1100
I-8	8500		4500		1400		78		23		500		b.d.		10700		2200		1300	
I-3-C		3600		5400		770		86		14		700		b.d.		8800		1000		1400
H-6		3100		4500		1300		120		19		1000		b.d.		13300		1100		1300
M-5-C	4700		5000		920		59		21		800		4		10200		1800		1100	
N-6		4400		5200		1000		87		22		700		3		9000		1700		1200
M-6-C		4600		4300		610		42		14		1000		b.d.		8600		1000		1200
J-3	4700	2400	3800	4100	1400	520	160	37	20	15	500	800	b.d.	b.d.	9400	12300	1300	1000	900	1400
M-4-C	4100	3200	5600	6100	1300	920	78	53	31	20	600	800	b.d.	2	12400.	12400	1500	1600	1200	1300
H-3-C		1500		3500		390		43		17		700		b.d.		7400		700		900
G-8-E	5300	2800		5000	1900	580	100	30	27	25	b.d.	600	b.d.	b.d.	8900	9700	1200	1500		1200
N-5		1900		6900		720		25		12		600		2		7700		1500		1000
H-4	2500	3200	3200	4700	680	1100	51	44	24	20	500	800	b.d.	b.d.	8500	10000	900	1300	700	1200
M-3-C	1900	4300	3700	4800	840	620	68	41	15	20	700	700	b.d.	b.d.	14700	9300	1100	800	1400	1400
$\bar{x}$	3286.7	4000	4211	4695	1120.7	784.2	118.1	65.6	20.3	17	656	800			11750	10250	1307	1142	1178	1221
S.D.	1926.8	2243.5	757.0	811.0	478.3	223.6	79.7	30.7	5.4	3.7	151.0	149.0			1987.0	2636.0	363.0	283.0	268.0	140.0

TABLE: 4 Cont. Lichen non-metal analyses for 1970 and 1983 (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay. A blank indicates that either there was no sample or that there was no analysis. b.d. indicates the amount is below detection limit. Detection limits in micrograms/gram: B<1.0, C1<100.0, F<1.0.

EVERNIA MESOMORPHA:

SITE	Ca		K		Mg		Na		B		C1		F		N		P		S	
	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
J-5	1600	2200		4400	580	1100	81	190	7	10		200	b.d.	b.d.	11100	13200	600	900		1600
I-7	420	1600		6100	250	810	48	130	3	10		200	b.d.	b.d.		15400		1500		1900
I-6	720	2000	3600	4600	950	860	110	110	7	9	100	500	b.d.	b.d.	16800	16900	800	1000	1900	1700
H-5-C	1800	1300	3900	4000	670	560	62	88	6	8	200	200	b.d.	b.d.	10900	12500	1100	1100	1300	1500
I-8	940				710		87		9				b.d.		19300		1200			
$\bar{x}$	1096	1775	3750	4775	632	832.5	77.6	129.5	6.4	9.3	150	300			14520	14500	925	1125	1600	1675
S.D.	585.7	403.1	212.0	918.0	253.6	221.4	23.8	43.8	2.2	1.0	71.0	141.0			4197.0	2022.0	275.0	263.0	424.0	171.0

TABLE 5. Paired "t" test levels of significance between 1970 and 1983 lichen samples. % = percent of change with 1970 being the base. Values are in micrograms per gram. N.S = no significant difference. b.d = below minimum detection limit.

		Cladina mitis				*Umbilicaria* sp.				*Parmelia sulcata*				*Evernia mesomorpha*				All Species Combined			
		(n=14)				(n=8)				(n=12-17)				(n=2-4)				(n=31-38)			
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Cu	70	7.0	2.2	-14	N.S	11.0	4.4	0	N.S	22.4	5.5	-40	0.01	10.5	3.9	33	N.S	13.1	7.7	-21	N.S
	83	6.0	2.2			11.0	5.7			13.5	7.8			14.0	2.9			10.3	6.2		
Cd	70	0.5	0.2	-40	0.001	0.6	0.2	17	N.S	1.2	0.3	-25	0.01	0.5	0.1	20	N.S	0.7	0.4	-14	N.S
	83	0.3	0.1			0.7	0.5			0.9	0.3			0.6	0.2			0.6	0.4		
Cr	70	3.0	1.6	-37	0.05	4.5	1.8	-11	N.S	6.8	3.6	-53	0.01	3.8	1.7	40	N.S	4.6	2.9	-33	0.01
	83	1.9	0.9			4.0	2.6			3.2	1.7			5.3	1.3			3.1	2.0		
Fe	70	1644.3	531.0	-33	0.01	3425.0	1328.5	-17	N.S	5050.0	2253.7	-66	0.001	2775.0	2091.9	25	N.S	3213.7	2086.6	-40	0.01
	83	1105.0	441.6			2845.0	2235.8			1742.5	856.8			3475.0	1281.6			1922.1	1440.0		
Hg	70	0.09	0.03	-56	0.001	0.24	0.10	-21	N.S	0.28	0.07	-46	0.001	0.54	0.09	-26	0.05	0.23	0.15	-39	0.01
	83	0.04	0.01			0.19	0.06			0.15	0.06			0.40	0.05			0.14	0.12		
Mn	70	65.9	37.6	-35	N.S	39.3	17.0	52	N.S	256.6	162.6	2	N.S	36.3	19.9	61	N.S	117.4	133.3	-.3	N.S
	83	42.6	24.9			59.8	57.7			261.7	124.0			58.5	7.6			117.1	124.0		
Mo	70	b.d				b.d				b.d				b.d				b.d			
	83	b.d	b.d			b.d				b.d				b.d				b.d			
Ni	70	3.1	1.4	19	N.S	4.5	1.6	-9	N.S	7.3	2.9	-55	0.001	3.5	1.7	43	N.S	4.7	2.7	-19	N.S
	83	3.7	7.1			4.1	3.3			3.3	1.2			5.0	2.2			3.8	4.5		
Pb	70	37.9	13.0	-64	0.001	78.1	37.0	-50	0.05	80.4	31.9	-48	0.01	29.0	13.8	-12	N.S	58.8	33.6	-51	0.001
	83	13.6	2.8			39.3	23.3			41.7	21.2			25.5	5.9			29.1	20.2		
Zn	70	39.6	10.6	-51	0.001	60.0	16.0	21	N.S	182.5	57.7	-12	N.S	45.3	13.2	19	N.S	89.6	72.4	-12	N.S
	83	19.4	4.5			72.3	44.1			160.0	34.4			53.8	6.7			78.6	65.4		
Al	70	1197.1	337.6	-35	0.001	2300.0	1142.7	-19	N.S	3141.7	939.5	-59	0.001	1347.5	628.0	26	N.S	2059.2	1144.5	-39	0.001
	83	778.6	254.4			1873.8	1294.6			1282.5	535.9			1700.0	678.2			1265.3	807.9		
As	70	2.16	0.47	-63	0.001	3.91	1.05	-39	0.01	5.59	1.06	-54	0.001	5.76	0.82	-43	0.01	3.99	1.77	-51	0.001
	83	0.80	0.28			2.40	0.67			2.57	0.80			3.31	0.98			1.96	1.12		

TABLE 5. continued

		Cladina mitis (n=14)				*Umbilicaria sp.* (n=8)				*Parmelia sulcata* (n=12-17)				*Evernia mesomorpha* (n=2-4)				All Species Combined (n=31-38)			
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Ca	70	1342.9	528.6	-36	0.01	867.5	901.6	35	N.S	2916.7	1220.2	55	N.S	1135.0	668.8	56	N.S	1717.9	1201.3	28	N.S
	83	863.6	250.4			1171.3	1088.0			4516.7	2585.9			1775.0	403.1			2177.9	2216.2		
K	70	1864.0	300.0	-19	0.01	3387.0	940.0	11	N.S	4057.0	790.0	13	N.S	3750.0	210.0	27	N.S	2874.0	1140.0	15	N.S
	83	1507.0	290.0			3750.0	830.0			4600.0	620.0			4775.0	920.0			3300.0	1550.0		
Mg	70	514.3	105.2	-28	0.001	558.8	226.0	4	N.S	1169.2	488.0	-35	0.05	612.5	288.5	36	N.S	740.8	423.0	-21	N.S
	83	368.6	110.2			581.3	355.4			759.2	196.6			832.5	221.4			585.5	278.9		
Na	70	52.9	19.2	-14	N.S	67.6	31.9	-.4	N.S	126.8	86.8	-50	0.05	75.3	26.8	72	N.S	81.7	60.3	-21	N.S
	83	45.6	20.2			67.3	33.4			63.8	30.5			129.5	43.8			64.7	37.2		
B	70	4.4	1.5	-23	N.S	6.5	2.0	28	N.S	20.4	5.9	-15	N.S	5.8	1.9	60	0.05	10.0	8.0	-6	N.S
	83	3.4	1.3			8.3	4.2			17.3	4.0			9.3	1.0			9.4	6.6		
Cl	70	b.d				b.d				657.0	150.0	23	0.05	150.0	70.0	100	N.S	161.0	280.0	81	N.S
	83	b.d				b.d				808.0	150.0			300.0	140.0			292.0	380.0		
F	70	b.d				b.d				b.d				b.d				b.d			
	83	b.d				b.d				b.d				b.d				b.d			
N	70	6414.3	1710.0	-29	0.001	10712.5	2028.0	16	N.S	11966.7	2072.0	-8	N.S	12933.3	3350.0	12	N.S	9189.2	3307.0	-4	N.S
	83	4585.7	692.0			12450.0	3101.0			10983.3	2758.0			14500.0	2022.0			8868.4	4418.0		
P	70	587.7	166.0	-28	0.01	975.0	406.0	13	N.S	1191.7	215.0	-5	N.S	833.3	252.0	35	N.S	486.5	507.0	-8	N.S
	83	421.4	105.0			1100.0	302.0			1133.3	264.0			1125.0	263.0			447.4	504.0		
S	70	471.0	170.0	-39	0.01	1325.0	400.0	28	N.S	1171.0	300.0	7	N.S	1600.0	420.0	5	N.S	923.0	510.0	12	N.S
	83	286.0	100.0			1700.0	520.0			1258.0	110.0			1675.0	170.0			1037.0	660.0		

TABLE 6 . Lichen sample - *Cladina mitis* - element inter-relationships based on Pearson correlation coefficients. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. DTB = Distance to Thunder Bay city; Alt = Altitude; DLS = Distance to Lake Superior.

		DTB	DLS	Alt	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
					1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
DTB						3*						1*		2*		1*				2*		1*			1	1										2*				3*	1					1*		
DLS				2																														1*												1*		
Alt																																																
Fe	1970												3		3																				1													
	1983											1		3		3				1						3						1				3				3								1
Mn	1970							1									2		1		3				1																		1	1	1		3	
	1983											1				2				2						1						1		1		1								1				1
P	1970									1	2				1				2														3	1	2							2			1		1	
	1983											2				1				2												1		2		1				1		1						
N	1970													1*	1		1		2								1				1		2		1				1						3		1	
	1983														1	2				3						1	1				1	3		3		2				2					1	3		3
Al	1970														3		2				2		3		1		2				2						3						1				1	
	1983															2										2						1		1		3				2								1
As	1970																2				1		1				1				2		1		2		1						1		2		1	1
	1983																			3						3						2		1		3				3								1
B	1970																		1		3		1		1		2				1						1				1		2		1		3	
	1983																																															
Ca	1970																																												2		2	
	1983																									2						1		2		3				3								1
Cd	1970																						2		2		1				1		1				2				1		2	2	1		3	
	1983																											1			1	2		1												1		1
Cl	1970																										2				2						3						3				1	
	1983																																															
Cr	1970																																		1						3						1	
	1983																															2				2				3								
Cu	1970																														1						2		1				1		2		1	
	1983																														1	1	2	1														
F	1970																																															
	1983																																															
Hg	1970																															1	3				2								2	1		1
	1983																																	2		1				1						1		3
K	1970																																	1	1										2			
	1983																																			2				1						2		3
Mg	1970																																						1			1			1			
	1983																																							3								1
Mo	1970																																										3				1	
	1983																																															
Na	1970																																												1			
	1983																																															
Ni	1970																																											1				
	1983																																															
Pb	1970																																											1	1	1	3	
	1983																																														1	
S	1970																																													1	2	
	1983																																															2
Zn	1970																																															
	1983																																															

TABLE 7. Lichen sample - Umbilicaria sp. - element inter-relationships based on Pearson correlation coefficients. Significance of correlations: 1≤0.05, 2≤0.01, 3≤0.001. A * indicates a negative correlation.

		DTB	DLS	Alt	Fe FEUT		Mn MNUT		P PPUT		N NN- TKUR		Al ALUT		As ASUT		B BBUT		Ca CAUT		Cd CDUT		Cl CLUT		Cr CRUT		Cu CUUT		F FFUT		Hg HGUT		K KKUT		Mg MGUT		Mo MOUT		Na NAUT		Ni NIUT		P PBUT		S SSUT		Zn ZNUT	
					1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
DTB									1		1						1																				1										2	
DLS				1													1*					1																										
Alt																		1*						1																								
FE	1970																								1						2								2		3							
	1983						2*							1	1	2						1				1		1			1	1			1*					2		2						
MN	1970																1																1															
	1983									1		2		3		1				3		1				1		1								2						1				1		
P	1970										2																										2										2	
	1983											2		1				1		2		1			1*									1		1										2		1
N	1970																																							1*								
	1983													1						2														2		1					1*					2		
AL	1970													1*			1		3									1*					2		3										2			
	1983															1				3		2				2		2								2						2						
AS	1970																		1*		1						1				1								1	2				1				
	1983																			1		2						2								1				2								
B	1970																		1														2		2										1		2	
	1983																			1							1*							2					1*				1			1		3
CA	1970																																2		3										3			1
	1983																					2				1		2						1		3					1*	1				1		
CD	1970																										2																2					
	1983																									2		3								2						3						
CL	1970																																															
	1983																																															
CR	1970																											1*													1							
	1983																											2								1						3			1*			
CU	1970																																						2	1	1		1					
	1983																																1*		1*	2						3						
F	1970																																															
	1983																																															
HG	1970																															1							2	3	1							
	1983																																															
K	1970																																		3										2		1	
	1983																																													3		2
MG	1970																																												2		1	
	1983																																								1	1				1		
MO	1970																																											2			1	
	1983																																											1				
NA	1970																																							2	2							
	1983																																									1						
NI	1970																																															
	1983																																												1*			
PB	1970																																															1*
	1983																																															
S	1970																																														1	1
	1983																																															1
ZN	1970																																															
	1983																																															

TABLE 8. Lichen sample - Parmelia sulcata - element inter-relationships based on Pearson correlation coefficients for 1970 and 1983. Signifiance of correlations: 1≤0.05, 2≤0.01, 3≤0.001. A * indicates a negative correlation.

	DTB	DLS	Alt	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
DTB				1*												1	2							1*									1					1*	2*								3
DLS			1					1*		2*				1*													1*			1*		1*									1*	1*	1*	1*			
Alt					1*		1			1*												1*			1*		1*														1*	1*	1*	1*		1*	
Fe 1970												3								1				3		3				1				2				2	2	3							
1983										1	1		3										1		3		2				2				3				2		3	1	2				
Mn 1970										2*								1		1		1*												1										1*			
1983																1*																													1	1*	
P 1970																																2															
1983																1		1				2											2													1	
N 1970														1				1*												1												2	1	3			
1983																			1										2																		
Al 1970																				1				3		3								3				3	1	3							
1983																				1*			1		3		1				2				2				2		3	1	3				
As 1970																				1		1								2												1		2			
1983																					1				1																				1		
B 1970																		1																					1*							3	
1983																																	1					1*									3
Ca 1970																						1*												1													1
1983																													2																1*		
Cd 1970																										1								2	1*					1							
1983																																	2														
Cl 1970																									1					2												1	1	2			
1983																								1	1	1					2							1	2			2	2				
Cr 1970																										3							1*	2				3	2	3							
1983																											1				2				2				2		3	1	2				
Cu 1970																																		2				3	2	3							
1983																															3	2	1		1						2		1				
F 1970																																															
1983																																2															
Hg 1970																																										1		3			
1983																																2			1						1		2				
K 1970																																															
1983																																						1*		1*						1	
Mg 1970																																						2		3							
1983																																									2		1				
Mo 1970																																															
1983																																															
Na 1970																																							1	3							
1983																																								1	2	1	1			1*	1*
Ni 1970																																															
1983																																											2				1*
Pb 1970																																											3	2			
1983																																															
S 1970																																															
1983																																															
Zn 1970																																															
1983																																															

TABLE 9. Lichen sample -*Evernia mesomorpha* - element inter-relationships based on Pearson correlation coefficients. Significance of correlations: 1≤ 0.05, 2≤ 0.01, 3 ≤0.001. An asterisk indicates a negative correlation. DTB = Distance to Thunder Bay city; Alt = Altitude, DLS = Distance to Lake Superior.

		Fe	Mn	P	N	Al	As	B	Ca	Cd	Cl	Cr	Cu	F	Hg	K	Mg	Mo	Na	Ni	Pb	S	Zn
	DTB DLS Alt	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983	1970 1983
DTB		1*	1*	1			1		1*			1*					2*		1*	1*			
DLS						1*	1												1*				
Alt									1						1						1		
Fe	1970				1	2				1	1	1					1		1	3			
	1983					1	1*					3					2		1	1			
Mn	1970		1*	2			1*	1*					1*								1		1*
	1983			2*				2															
P	1970			1				1*									1*						
	1983							2*					1*										1*
N	1970				1	1			1*											2	1*		
	1983														1*						2*		
Al	1970									1	1	2					1		1	2			
	1983						1*					1							1	1			
As	1970											1*					1*		2*				
	1983									1*1			1				1*				1*		
B	1970												1										1
	1983												1										
Ca	1970																				1	1*	1*
	1983																1			1			
Cd	1970									1*		2					2						
	1983											1*	1*				1*						
Cl	1970																						
	1983																		1	1			
Cr	1970																1			1			
	1983																1		2	2			
Cu	1970																1						
	1983																						
F	1970																						
	1983																						
Hg	1970														1*								
	1983																				1		
K	1970																						
	1983																				1*	1	1*
Mg	1970																			1			
	1983																		1	1			
Mo	1970																						
	1983																						
Na	1970																			1			
	1983																			1			
Ni	1970																						
	1983																						
Pb	1970																					1*	1*
	1983																						
S	1970																						
	1983																						
Zn	1970																						
	1983																						1

TABLE 10. Combined lichen sample element inter-relationships based on Pearson correlation coefficients for 1970 and 1983. Significance of correlations: 1≤ 0.05, 2 ≤0.01, 3≤ 0.001. An asterisk indicates a negative correlation. DTB = Distance to Thunder Bay city. Alt = Altitude; D̄LS = Distance to Lake Superior.

		DTB	DLS	Alt	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
					1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983	1970	1983
DTB					1*	2*								1*		1*										1*					1*					1*	2		1*	3*								
DLS			3																																								1*					
Alt							1	1																														1*										
Fe	1970						3	3	2	2	3	2	3		3	1	3	3	2	3	3	1	3	3	3		3				3		3	2	3	1			3	1	3		3	2	3	1	3	3
	1983									2		3		3		3			1*			3				3		3			3	3		1		3		1		3		1		2		2		
Mn	1970							3	2	1					2		3	3	3	1	3	1	3	3	3		3						1	1	3				3		3							3
	1983								2	2	2	1				2		3	3	3	3	2	3	3	3		3						2	3	3	2			3		3		2	1		1	3	3
P	1970									3	3	3	3		3	2	3	3	3	2	3	3	2	3	2		3	1			2	1	3	3	3				1		3		3	3	3	3	3	3
	1983										3	3		3		3		3	1	2	1	3	1	3		3	3	3		1	3	3	3	3	1	3				1	1		1	3	3	3	3	3
N	1970											3	3	1	3	3	3	3		3	2	2	3	3	3	1	3	2			3	3	3	3	2	3			2	1	3		3	3	3	3	3	3
	1983													3		3		3		2		3	1	2		3	1	3		1	3	3	3	3		3				2			1	3	3	3	1	3
Al	1970														3		3	3	3	3	3	1	3	3	3		3				1		3	3	3									1		2		3
	1983														1	3						3				3		3			1	3		2		3				2		1		3		3		
As	1970															3	3	3	1	3	3	3	3	3	3	2	3	3			3	3	3	3	3	3				3				3		3		3
	1983																2	3		2		3	3	3		3	1	3			3	3	3	3		3				3				3	3	3	2	3
B	1970																	3	3	3	3	3	3	3	2		3	2		3			3	3	3	2								2		2		3
	1983																		3	3	3	3	3	3	1		3	3			2	1	3	3	3	3			1		3		1	3	3	3	3	3
Ca	1970																			2	3		3	3	2		3			1			2	1	3			1*	1		3						3	3
	1983																				3	2	3	3	2		3	1		3	1		3	3	3	3			3		3		1	1	1	1	3	3
Cd	1970																					3	3	3	3		3						3	2	3				3		3		3	1			3	3
	1983																						3	3		3	3	3			2	2	2	3		3							1	3	1	3	3	3
Cl	1970																							3	2		3	2			1	1	3	3	3	2			2		3		3	3	1		3	3
	1983																								3		3	2		1	2		3	3	3	3			3		3		2	3	1	1	3	3
Cr	1970																										3				1		3	1	3				3		3		2	1	1		1	2
	1983																											3			3	3	1	3		3				3			1	3	1	3	2	
Cu	1970																											2			2		3	3	3	2			3		3		3	3	2	1	3	3
	1983																													1	2	3	3	3		3				2			1	3	1	3		2
F	1970																																															
	1983																																2			1											3	
Hg	1970																															3	3	3	1	3			1	3	1			1	3	3		1
	1983																																3	3		3				3				2	3	3		
K	1970																																	3	3	2			2		3		2	3	3	3	3	3
	1983																																		2	3				1	1		1	3	3	3	3	3
Mg	1970																																						3		3		1		1		3	3
	1983																																							3				2	1	3	2	3
Mo	1970																																					1										
	1983																																											2				
Na	1970																																							1	3		2				1	1
	1983																																											1	1	1		
Ni	1970																																										3	2	2		3	3
	1983																																															
Pb	1970																																											3	2	1	2	2
	1983																																												3	2	2	2
S	1970																																													3	1	3
	1983																																														1	3
Zn	1970																																															3
	1983																																															

TABLE 11. Conifer bark pH values for 1970 and 1981 sample sites. $H^+\bar{X}$ based on hydrogen ion concentrations. $A\bar{X}$ = means are arithmetic means. A.S.D. = arithmetic standard deviation.
LU = means from 1981 (Barclay) report. DBH = diameter at breast height.

	White Spruce		Black Spruce		Jack Pine		White Pine		Tamarack		White Cedar	
SITE	1970	1981	1970	1981	1970	1981	1970	1981	1970	1981	1970	1981
J-6										3.6		
K-6-C	3.3	4.8		3.4							4.5	
K-8	3.2	5.6									4.3	3.7
I-4-C	3.4					3.5						
J-3-C	3.9	4.2		3.6								
J-4		3.9				3.3						
K-3-C			3.4	3.2		3.4						
1-9-E												
N-6		3.7					2.9	2.8				
I-8-S	4.1	4.1										
M-4				3.5					3.7	3.7		
1-9-S				3.8				3.3				
G-4-C				4.2	5.4	3.6						
H-9		3.6					3.3	3.3				
G-9-E		3.8					3.4	3.3				
G-8		4.4				3.4						
F-7-C	4.1	4.1			3.4	3.4						
G-4			3.5	3.5		3.4						
N-3				3.4		3.3						
F-4-C	3.9	3.9			3.4	3.5						
N-2-C		3.9	3.5	3.9								
G-2			3.1	3.3	3.2	3.3						
E-4		4.1		3.6								
G-1-C		5.2	3.6	3.6	3.4	3.6						
F-1-C	4.5	4.5			3.6	3.5						
D-4		3.8			3.1	3.1						

cont.

TABLE 11. continued

	White Spruce		Black Spruce		Jack Pine		White Pine		Tamarack		White Cedar	
SITE	1970	1981	1970	1981	1970	1981	1970	1981	1970	1981	1970	1981
n	8	16	5	12	7	13	3	4	1	2	2	1
$H^+\bar{X}$	3.6	4.0	3.4	3.6	3.4	3.4	3.1	3.1	3.7	3.7	4.4	3.7
$A\bar{X}$	3.8	4.2	3.4	3.6	3.6	3.4	3.2	3.2	3.7	3.7	4.4	3.7
A.S.D.	0.5	0.6	0.2	0.3	0.8	0.1	0.3	0.3	0.0	0.1	0.1	0.0
$LU\bar{X}$	4.1	4.3	3.6	3.9	3.7	3.9	3.4	3.5	3.8	3.9		5.6
$DBH\bar{X}$	28.5	31.0	20.8	21.6	31.5	31.8	33.0	50.0	21.6	21.8		21.6

TABLE 12. Deciduous bark pH values for 1970 and 1981 sample sites. H^+ based on hydrogen ion concentrations. $A\bar{X}$ = means are arithmetic means. A.S.D. = arithmetic standard deviation.

LU = means from 1981 (Barclay) report.
DBH = diameter at breast height.

	2		10		9		3	
	White Birch		T. Aspen		B. Poplar		B. Ash	
SITE	1970	1981	1970	1981	1970	1981	1970	1981
J-6								
K-6-C	4.3	4.1	4.7	4.5				
K-8	3.6	3.4						
I-4-C								
J-3-C	3.5	4.0	4.5	5.1				
J-4	3.5	4.0	4.9	4.5				
K-3-C		3.8	4.6					
1-9-E	3.9	4.0						
N-6			4.3					
1-8-S	3.8					7.2	6.4	7.1
M-4		5.0			4.6	4.5		
1-9-S		3.7						
G-4-C								
H-9		4.0				5.9		
G-9-E			4.9			5.4		
G-8		4.2			5.3	5.5		
F-7-C			4.7	5.0		4.2		
G-4			4.5	5.3				
N-3		4.2						6.4
F-4-C		3.8	5.4	6.4				
N-2-C		4.2				5.1		
G-2			3.4	5.9	5.1	7.4		
E-4				4.5				
G-1-C		3.8						
F-1-C		4.1		4.8				
D-4		4.0		5.2				
n	6	16	10	10	3	8	1	2
$H^+\bar{X}$	3.7	3.9	4.2	4.9	4.9	4.9	6.4	6.6
$A\bar{X}$	3.8	4.0	4.6	5.1	5.0	5.4	6.4	6.8
A.S.D.	0.3	0.3	0.5	0.6	0.4	1.0	0.0	0.5
$LU\bar{X}$	4.0	4.6	5.1	5.3	5.6	5.7	6.5	6.6
$DBH\bar{X}$	19.6	19.3	23.6	23.4	19.6	22.6	23.6	22.4

TABLE 13.
Conifer Bark Heavy Metal Analyses For 1970-71 and 1981.
(10 Heavy Metals, Plus Al and Metalloid As).
Units Are Micrograms Per Gram.
The Sample Sites Are Arranged In Order
Of Increasing Distance From Thunder Bay.
b.d = below detection limits
(Cr<0.5, Mo<0.5, Ni<1.0)

WHITE SPRUCE

Site	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
	70-71	81	70-71	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
K-6-C	6	8	0.3	0.4	b.d	b.d	200	250	0.16	0.07	125	94	b.d	b.d	b.d	5	1	12	94	126	160	170	0.45	0.08
K-8	7	9	0.4	0.6	4	7	200	600	0.12	0.20	282	112	b.d	b.d	2	3	2	4	130	46	130	460	0.07	0.21
I-4-C	2	4	b.d	0.1	6	4	250	800	0.14	0.34	75	56	b.d	b.d	3	2	2	9	19	23	140	510	0.14	0.13
J-3-C	6	5	0.2	0.2	b.d	b.d	100	50	0.12	0.06	137	198	b.d	b.d	b.d	b.d	4	3	63	88	110	100	0.25	0.18
J-4	-	4	-	b.d	-	2	-	200	-	0.09	-	152	-	b.d	-	1	-	4	-	108	-	160	-	0.35
N-6	6	4	0.2	0.1	2	4	400	100	0.28	0.10	102	126	b.d	b.d	1	b.d	11	4	87	71	440	-	0.39	-
I-8-S	7	5	0.3	b.d	2	1	100	50	0.06	0.09	70	48	b.d	b.d	b.d	b.d	4	3	113	90	90	50	0.14	0.22
H-9	9	8	0.0	b.d	b.d	b.d	200	100	0.21	0.09	27	25	b.d	b.d	b.d	b.d	2	1	36	79	130	40	0.21	0.13
G-9-E	-	7	-	0.1	-	b.d	-	150		0.04	-	79	-	b.d	-	b.d	-	2	-	100	-	80		0.12
G-8	-	4	-	0.2	-	4	-	1400	-	0.10	-	143	-	b.d	-	4	-	4	-	143	-	450	-	0.68
F-7-C	6	7	0.1	0.3	b.d	b.d	400	1000	0.06	0.12	108	130	b.d	b.d	b.d	1	2	4	71	100	110	220	0.12	0.43
F-4-C	6	6	0.2	0.2	2	b.d	75	150	0.04	0.05	166	182	b.d	b.d	b.d	1	2	2	101	112	75	120	0.24	b.d
N-2-C	6	7	0.1	0.2	2	1	650	200	0.18	0.09	73	60	b.d	b.d	1	1	8	4	144	128	690	170	0.29	0.12
E-4	4	3	0.2	0.2	b.d	b.d	150	100	0.16	0.05	191	122	b.d	b.d	b.d	b.d	5	5	80	74	160	120	0.50	0.19
G-1-C	-	6	-	0.1	-	b.d	-	100	0.10	0.03	-	171	-	b.d	-	b.d	-	4	-	86	-	140	0.25	b.d
F-1-C	6	6	0.2	0.3	2	b.d	250	750	0.04	0.09	168	206	b.d	b.d	1	2	3	3	70	79	220	610	0.04	0.04
D-4	6	4	0.2	0.1	2	2	600	450	0.19	0.14	173	180	b.d	b.d	b.d	2	4	3	72	118	410	260	0.36	0.09
$\overline{x}$	5.9	5.7	0.20	0.20	2.1	2.0	275.0	379.4	0.13	0.10	130.5	122.6	-	-	1.2	1.7	3.8	4.2	83.1	92.4	220.4	219.4	0.25	0.18
s.d.	1.6	1.8	0.09	0.14	1.4	1.7	185.4	396.1	0.07	0.07	66.6	55.6	-	-	0.6	1.2	2.8	2.6	34.7	30.2	182.0	177.0	0.09	0.18

TABLE 13. (Cont'd)
BLACK SPRUCE

Site	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
	70-71	81	70-71	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
K-6-C		5		0.5		11		300		0.10		440		b.d		6		6		46		130		0.61
J-3-C	5	3	0.3	0.3	b.d	1	350	100	0.19	0.09	346	197	b.d	b.d	b.d	1	3	3	82	56	320	60	0.52	0.19
K-3-C	5	3	0.2	0.1	1	2	450	350	0.10	0.12	38	249	b.d	b.d	1	2	7	2	21	36	490	230	0.06	0.09
M-4	4	4	0.1	0.2	7	3	700	200	0.27	0.08	59	145	b.d	b.d	3	4	4	3	61	59	330	70	0.70	b.d
T-9-S	3	8	0.1	0.2	b.d	1	650	200	0.12	-	47	106	b.d	b.d	b.d	1	6	8	85	95	420	130	0.35	b.d
G-4-C	9	5	0.2	0.1	b.d	b.d	750	150	-	0.08	69	61	b.d	b.d	2	1	b.d	2	76	84	400	90	-	0.17
G-4	3	3	0.0	0.1	6	b.d	150	200	0.11	0.12	143	158	b.d	b.d	4	1	3	6	38	43	110	160	0.32	0.31
N-3	4	2	0.4	0.3	4	1	350	150	0.26	0.16	261	265	b.d	b.d	3	2	7	4	73	82	360	160	0.23	0.0
N-2-C	5	7	0.3	0.2	2	1	850	450	0.28	0.06	77	123	b.d	b.d	1	2	8	5	77	155	760	470	0.29	0.21
G-2	5	3	0.1	0.1	2	7	300	300	0.24	0.16	232	178	b.d	b.d	2	4	2	3	75	52	290	200	0.44	0.12
E-4	4	2	0.2	0.2	2	b.d	500	200	0.23	0.10	244	237	b.d	b.d	2	1	5	5	39	42	400	150	0.76	0.30
G-1-C	3	3	0.1	0.2	b.d	b.d	150	200	0.14	0.19	207	251	b.d	b.d	b.d	b.d	3	5	40	36	110	150	0.12	0.07
$\overline{x}$	4.7	3.6	0.19	0.21	2.6	2.6	472.7	233.3	0.20	0.12	156.6	200.8	-	-	1.9	2.2	4.5	4.2	55.5	64.7	362.7	166.7	0.38	0.17
s.d.	1.6	1.4	0.10	0.12	2.1	3.2	239.1	98.5	0.07	0.04	106.0	98.9	-	-	1.0	1.6	2.3	1.5	22.4	33.7	177.8	107.5	0.23	0.18
JACK PINE																								
I-4-C	5	3	0.4	0.9	7	4	450	200	0.16	0.06	37	38	b.d	b.d	4	2	3	1	36	35	600	330	0.32	0.01
J-4	6	2	0.7	0.2	b.d	b.d	450	200	0.18	0.12	44	31	b.d	b.d	2	b.d	13	2	62	29	740	660	0.95	0.0
K-3-C	8	4	0.3	0.2	3	1	950	500	0.12	0.06	37	34	b.d	b.d	3	2	9	7	31	23	930	590	0.18	0.06
I-9-E	5	5	0.6	0.7	b.d	5	350	150	0.06	0.06	62	84	b.d	b.d	1	4	5	4	56	61	620	420	0.23	0.0
G-4-C	3	4	0.3	0.4	b.d	b.d	350	400	0.08	0.11	60	49	b.d	b.d	b.d	2	4	5	38	35	390	410	0.26	0.41
G-8	7	3	0.7	0.6	6	2	4100	1750	0.19	0.09	39	46	b.d	b.d	4	3	6	4	41	38	1400	740	1.90	4.83
F-7-C	3	4	0.4	0.3	b.d	b.d	400	250	0.06	0.04	79	94	b.d	b.d	b.d	b.d	1	b.d	34	35	490	480	0.12	0.10
G-4	6	3	0.3	0.2	6	5	650	300	-	0.08	23	19	b.d	b.d	4	3	8	5	32	27	930	650	-	0.30
N-3	5	3	0.6	0.4	b.d	6	400	200	0.18	0.10	68	53	b.d	b.d	b.d	3	8	4	54	29	560	460	0.14	0.0
F-4-C	5	4	0.2	0.3	b.d	b.d	550	300	0.12	0.06	42	49	b.d	b.d	2	2	4	5	38	35	810	660	0.14	0.05
G-2	3	3	0.2	0.1	b.d	4	350	250	0.10	0.07	44	43	b.d	b.d	b.d	2	3	b.d	33	25	370	250	0.12	0.06
G-1-C	4	3	0.3	0.2	1	b.d	350	150	0.18	0.05	116	53	b.d	b.d	1	b.d	2	3	32	36	550	380	0.12	0.0
F-1-C	5	3	0.2	0.2	4	3	400	500	0.10	0.07	35	56	b.d	b.d	5	4	3	2	26	28	650	630	0.19	0.15
D-4	3	3	0.2	0.1	1	b.d	300	250	0.13	0.07	22	22	b.d	b.d	b.d	1	2	3	13	11	490	380	0.12	b.d
$\overline{x}$	4.9	3.4	0.38	0.30	2.5	2.6	717.9	385.7	0.13	0.07	50.6	47.9	-	-	2.2	2.2	5.1	3.4	37.6	31.2	680.7	502.9	0.37	0.43
s.d.	1.6	0.7	0.19	0.18	2.3	1.9	987.9	408.8	0.05	0.02	25.0	20.9	-	-	1.5	1.1	3.4	1.8	12.7	11.0	271.5	150.1	0.51	1.27

TABLE 13. (Cont'd)

Site	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
	70-71	81	70-71	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
WHITE PINE																								
N-6	2	1	0.2	0.1	b.d	b.d	250	b.d	0.24	0.04	32	29	b.d	b.d	b.d	1	2	b.d	32	19	390	200	0.09	0.12
I-9-S	3	2	0.2	0.2	b.d	b.d	400	250	0.01	0.02	15	20	b.d	b.d	1	1	4	21	35	33	490	370	0.22	0.10
H-9	3	4	0.2	0.3	b.d	b.d	b.d	500	0.10	0.10	4	30	b.d	b.d	b.d	b.d	b.d	3	30	36	50	310	0.03	0.12
G-9-E	5	5	0.3	0.4	1	b.d	850	400	0.08	0.06	253	24	b.d	b.d	2	2	2	2	48	28	550	230	0.25	0.12
$\overline{x}$	3.3	3.0	0.23	0.25	-	-	387.5	250.0	0.11	0.06	76	25.8	-	-	1.2	1.0	2.0	6.3	36.3	29.0	370.0	277.5	0.15	0.12
s.d.	1.3	1.8	0.05	0.13	-	-	340.0	147.2	0.10	0.03	118.6	4.6	-	-	0.5	0.5	1.3	9.5	8.1	7.4	223.3	77.2	0.11	0.01
BALSAM FIR																								
J-6		5.1		0.8		b.d		200		-		213		b.d		b.d		7		69		80		-
$\overline{x}$		-		-		-		-		-		-		-		-		-		-		-		
s.d.																								
TAMARACK																								
J-6	-	4	-	0.5	-	b.d	-	300	-	0.06	-	340	-	b.d	-	b.d	-	6	-	49	-	130	0.58	0.24
M-4	13	6	0.3	0.3	6	6	750	600	0.20	0.10	251	160	b.d	b.d	7.0	11	4	6	60	79	350	180	0.21	0.0
$\overline{x}$	-	5.0	-	0.4	-	-	-	450	-	0.08	-	250.0	-	-	-	-	-	6.0	-	64.0	-	155.0	0.40	0.12
s.d.	-	1.4	-	0.14	-	-	-	212	-	0.03	-	127.3	-	-	-	-	-	0	-	21.2	-	35.4	0.26	0.17
WHITE CEDAR																								
K-6-C	8	9	0.5	0.8	7	5	600	800	0.28	0.38	30	36	-	0.5	5	5	14	20	43	64	420	590	0.19	0.21
K-8	6	6	0.5	0.2	6	5	250	200	0.12	0.14	30	133	b.d	b.d	4	3	3	4	60	63	210	120	0.08	0.10
$\overline{x}$	7.0	7.5	0.50	0.50	6.5	5.0	425.0	500.0	0.20	0.26	30	84.5	-	-	4.5	4.0	8.5	12.0	51.5	63.5	315.0	355.0	0.14	0.16
s.d.	1.4	2.1	0	0.42	0.7	0	247.5	424.3	0.07	0.11	0	68.6			0.7	1.4	7.8	11.3	12.0	0.7	148.5	332.3	0.08	0.08

TABLE 14. Deciduous bark heavy metal analyses for 1970-71 and 1981. (heavy metals, plus Al and the metalloid As). Units are in micrograms per grams. The sites are arranged in order of increasing distance from Thunder Bay city.

WHITE BIRCH ELEMENT	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																								
J-6		8		0.4		2		600				204		b.d		2		31		142		270		
K-6-C	7	7	0.4	0.9	13	8	900	450	0.09	0.04	306	447	0.5	b.d	8	4	28	12	56	161	460	200	0.73	0.35
K-8	6	9	0.4	0.4	3	1	200	500	0.02	0.06	674	160	b.d	b.d	1	2	8	18	172	39	130	300	0.32	0.43
J-3-C	6	5	0.4	0.2	b.d	b.d	200	150	0.12	0.04	331	263	b.d	b.d	b.d	b.d	16	5	94	58	150	70	0.62	0.27
J-4	6	6	0.2	0.2	b.d	b.d	250	300	b.d	b.d	221	311	b.d	b.d	b.d	b.d	12	10	122	84	180	240	0.49	0.30
K-3-C	7	22	0.3	0.2	b.d	1	150	300	0.01	b.d	592	408	b.d	b.d	1	4	9	14	124	80	100	210	0.17	0.09
I-9-E	6	5	0.4	0.8	7	b.d	300	100	b.d	b.d	342	1209	b.d	b.d	4	b.d	11	5	164	181	160	50	0.46	0.12
I-8-S	6	6	0.5	1.0	b.d	16	100	200	0.02	0.01	111	280	b.d	b.d	b.d	8	8	4	204	253	80	70	0.44	0.12
M-4	6	6	0.2	0.2	5	6	200	150	0.05	0.03	81	163	b.d	b.d	3	3	9	6	34	42	80	100	0.35	0.12
I-9-S	7	5	0.7	0.9	b.d	b.d	250	150	b.d	b.d	168	333	b.d	b.d	b.d	b.d	21	5	116	132	180	90	0.51	0.09
H-9	8	7	0.4	0.9	b.d	b.d	300	450	0.07	0.05	80	325	b.d	b.d	b.d	b.d	17	9	54	222	200	200	0.53	0.34
G-8		6		0.5		1		750		0.04		357		b.d		1		9		251		300		0.49
N-3	8	7	0.3	0.3	19	12	250	150		0.03	165	225	b.d	b.d	9	6	24	7	29	55	305	110		
F-4-C	7	6	0.2	0.2	b.d	b.d	250	200	0.09	0.02	553	267	b.d	b.d	b.d	2	7	12	126	65	80	140	0.29	0.25
N-2-C	5	5	0.2	0.3	2	1	250	350		0.03	187	255	b.d	b.d	b.d	1	6	8	231	168	230	290	0.22	0.12
E-4	7	6	0.3	0.1	b.d	1	b.d	100	0.03	0.02	712	400	b.d	b.d	b.d	1	5	8	74	60	30	90	0.30	0.26
G-1-C	b.d	6	b.d	0.2	b.d	b.d	b.d	325	0.18	0.08	36	351	1	b.d		2	b.d	8	91	111	20	205	0.40	0.43
F-1-C	9	8	0.2	0.2	5	3	600	950	0.05	0.02	336	195	b.d	b.d	3	2	12	6	88	57	380	640	0.28	0.13
D-4	7	6	0.2	0.2	4	1	370	450	0.07	0.04	458	212	1	b.d	3	1	14	12	48	56	190	245	0.35	0.14
$\bar{X}$	6.4	7.2	0.32	0.43	3.9	3.1	275	333	0.06	0.03	315	335	0.8		2.4	2.3	12.2	10.0	108	118	174	201	0.40	0.21
S.D.	1.7	3.7	0.15	0.35	5.0	4.2	205	232	0.05	0.02	215	227	1.1		2.5	1.9	7.1	6.3	59	70	119	132	0.15	0.15

TABLE 14 continued

TREMBLING ASPEN

ELEMENTS	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																								
K-6-C	11	8	1.3	1.1	6	9	400	300	0.17	0.08	85	37	b.d	b.d	3	5	6	7	205	134	280	150	0.36	0.08
K-8	8	6	1.0	2.3	5	8	150	150	0.06	0.03	25	37	b.d	0.05	3	4	8	2	86	194	110	110	0.10	0.21
I-4-C		9		1.0		2		200				48		b.d		2		6		194		180		0.01
J-3-C	7	5	0.5	0.8	1	1	100	100	0.01	0.03	19	56	b.d	b.d	b.d	b.d	4	5	109	122	90	100	0.14	0.10
J-4	8	7	0.5	0.8	b.d	1	100	100	0.04	0.03	40	44	b.d	b.d	b.d	2	3	3	123	125	100	80	0.31	0.09
K-3-C	8	6	0.5	1.4	b.d	b.d	b.d	100	0.01	0.01	31	66	b.d	b.d	b.d	b.d	2	4	91	159	50	90	0	0
I-9-E		4		1.3		4		100		0.02		72		b.d		6		4		252		40		0
N-6	6	4	0.3	0.2	2	b.d	450	200	0.27	0.11	32	25	b.d	b.d	b.d	b.d	4	5	110	87	570	180	0.17	0
I-9-S	8	4	1.3	1.8	1	b.d	400	72		0.01	28	16	b.d	b.d	1	b.d	8	4	95	183	440	50	0.14	0
G-4-C		9		2.3		b.d		650				102		b.d		1		14		212		420		
G-9-E	9		1.6		b.d		150		0.02		196		b.d		b.d		3		170		170		0	
F-7-C	9	8	0.8	0.9	b.d	b.d	200	250	0.02	0.01	32	35	b.d	b.d	b.d	b.d	2	4	105	98	90	100	0.1	0.1
G-4	6	5	0.8	1.2	2	3	b.d	150	b.d	0.01	18	44	b.d	b.d	b.d	1	2	4	90	177	50	120	0.02	0.17
F-4-C	11	5	1.2	0.7	1	b.d	200	100	0.02	0.02	105	94	b.d	b.d	b.d	1	4	3	154	144	160	120	0	0
G-2	6	9	0.7	1.2	7	2	150	400	0.02	0.04	40	174	b.d	b.d	4	1	4	11	148	219	130	430	0.01	0.2
E-4		4		0.5		b.d		50		0.02		28		b.d		b.d		3		66		60		0.18
F-1-C		9		0.8		6		800	0.10	0.02		160		b.d		6		8		120		690	0.63	0.14
D-4		7		0.5		b.d		150	0.14	0.02		140		b.d		b.d		2		93		110	0.12	0.05
$\bar{X}$	8.1	6.4	0.88	1.11	2.4	2.6	200	228	0.07	0.03	54	69			1.6	2.1	4.2	5.2	124	152	187	178	0.15	0.08
S.D.	1.7	2.0	0.41	0.59	2.2	2.6	140	209	0.08	0.03	52	49			1.1	1.9	2.2	3.2	38	53	163	173	0.18	0.08

TABLE 14 continued

BALSAM POPLAR

ELEMENTS	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																								
I-4-C		7		1.2		6		250	0.10	0.03		20		b.d		4		6		185		230	0.01	0.01
I-8-S		8		2.0		b.d		200		0.04		42		b.d		b.d		5		219		190		0.29
M-4	6	7	1.0	0.9	8	5	150	100	0.03	0.02	19	15	b.d	b.d	4	3	5	11	173	180	80	70	0	0
G-4-C		7		0.9		b.d		350		0.05		33		b.d		1		6		160		270		0.24
H-9		9		1.2		b.d		150	0.12	0.03		28		b.d		b.d		3		224		130	0.35	0.12
G-9-E		6		1.1		2		1450		0.02		67		b.d		2		10		159		790		0.12
G-8	5	6	0.8	1.0	b.d	2	150	800	0.03	0.04	25	36	b.d	b.d	b.d	2	4	5	144	161	90	380	0.14	0.41
F-7-C	12	9	0.8	0.6	b.d	b.d	2200	250	0.12	0.06	136	53	b.d	b.d	b.d	b.d	6	2	140	129	600	100	0.45	0.10
G-4	7		1.1		3		250				86		b.d		2		6		169		240		0.39	
N-2-C	10	7	1.5	1.6	14	1	2250	150	0.08	0.03	55	75	b.d	b.d	9	1	5	6	217	216	1850	160	0.70	0
G-2	6	6	0.4	0.6	b.d	1	b.d	100	0.04	0.01	46	74	b.d	b.d	b.d	1	3	2	166	260	50	140	0.01	0.01
X̄	7.7	7.2	.93	1.11	8.3	2.1	1000	380	0.07	0.03	61.2	44			5.0	1.7	4.8	5.6	168	189	485	246	0.26	0.13
S.D.	7.5	1.1	.85	0.43	4.8	1.9	968	428	0.04	0.02	67	22			4.9	1.1	2.0	3.0	128	40	602	211	0.26	0.14

BLACK ASH

ELEMENTS	Cu		Cd		Cr		Fe		Hg		Mn		Mo		Ni		Pb		Zn		Al		As	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																								
J-6		16		0.5		2		600		0.07		161		b.d		2		20		63		340		0.93
I-8-S	18	18	0.2	0.1	10	1	850	200	0.17	0.06	63	54	b.d	b.d	5	2	6	6	38	26	920	190	1.11	0.14
N-3	15	11	0.6	0.3	1	b.d	600	200		0.07	244	171	b.d	b.d	1	b.d	13	6	53	48	740	220	0.35	0
X̄	16.5	15.0	0.40	0.30	5.5	1.3	725	333		0.07	154	129			3.0	1.7	9.5	10.7	46	46	830	250	0.73	0.36
S.D.	2.1	3.6	0.28	0.20	6.4	0.6	177	231		0.01	128	65			2.8	0.6	5.0	8.1	11	19	127	79	0.54	0.50

TABLE 15. Conifer tree bark non-metal analyses for 1970-71 and 1981. (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay city. b.d = below detection limit (B<1.0, Cl<100.0, and F<1.0)

WHITE SPRUCE

SITE	Ca		K		Mg		Na		B		Cl		F		N		P		S	
	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
K-6-C	20500	23400	400	700	150	620	17	65	5	10	b.d	b.d	4	4	3600	4300	200	200	800	400
K-8	19500	31900	700	600	270	330	14	34	10	15	b.d	100	8	12	3900	7000	200	400	300	1300
I-4-C	2310	1940	400	800	160	220	17	58	b.d	b.d	b.d	b.d	5	10	2100	4200	100	300	300	700
J-3-C	13000	14400	1600	1300	180	240	9	10	5	5	b.d	b.d	18	7	2400	2700	200	200	400	300
J-4		15200		1000		270		19		10		b.d	43	19	5400	2900	300	200		400
N-6	17600		900	900	270	230	35	14	b.d		b.d		23	12	4000		300		700	300
I-8-S	13000	13300	1000	1000	300	300	24	22	10	10	b.d	b.d	4	4	3300	2100	200	100	300	300
H-9	7570	7900	3900	1200	250	220	49	14	5	5	b.d	b.d	3	6	4400	3600	200	200	1400	300
G-9-E		11280		1000		320		11		5		b.d		8		2700		100		300
G-8		14150	2600	900		620		34		10	b.d	b.d	57	28	5500	2700	600	200	900	300
F-7-C	11000	18100	800	800	340	320	13	21	b.d	5	b.d	b.d	9	13	2500	4600	200	300	b.d	400
F-4-C	9120	9690	700	800	320	350	11	16	10	10	b.d	b.d	4	5	2700	2900	200	200	b.d	200
N-2-C	21300	12900	1300	2600	840	610	78	46	10	10	b.d	b.d	32	14	4200	2500	300	100	1000	400
E-4	15200	14500	1100	500	360	250	19	28	10	5	b.d	b.d	15	22	3200	1900	200	200	500	100
G-1-C		10690		1000		390		16		5		b.d		6	5000	3200	400	200		200
F-1-C	10770	13940	2400	2000	410	610	70	115	10	10	b.d	b.d	7	8	2500	3500	200	200	200	300
D-4	17310	16390	1600	1000	260	360	34	87	7	5	b.d	100	14	6	4600	3400	300	200	800	400
$\bar{X}$	13706	14387	1390	1060	316	368	30.0	35.9	7.5	7.6			16.4	10.8	3706	3288	256	200	560	390
S.D	5577	6387	990	520	175	150	22.6	29.7	2.5	3.1			16.1	6.8	1447	1258	134	100	390	270

cont....

TABLE 15 continued

BLACK SPRUCE

SITE	Ca		K		Mg		Na		B		Cl		F		N		P		S	
	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	71	81
K-6-C		10800		400		200		26		10		b.d		8		3200		200		800
J-3-C	7940	7390	500	300	240	160	20	18	5	b.d	b.d	b.d	17	11	4100	2400	200	200	700	300
K-3-C	2030	5060	300	400	250	300	19	130	b.d	10	b.d	200	14	12	2200	2600	200	700	100	600
M-4	4740	5680	700	300	250	210	24	18	5	5	b.d	b.d	19	16	3800	1900	200	100	1600	300
T-9-S	2920	11200	300	b.d	160	790	20	51	5	5	b.d		21	22	3700	3100	300	200	400	
G-4-C	14000	10400	1300	700	530	320	95	21	10	10	100	b.d	12	14	4500	2600	300	200	800	300
G-4	7360	9140	600	400	340	320	41	39	5	10	b.d	b.d	14	19	2500	3400	100	200	500	400
N-3	8150	8720	500	500	260	310	26	15	5	5			20	16	3900	3000	300	200	600	500
N-2-C	9330	13600		800	960	1120	61	56	10	10		200	42	26	3900	2600	300	200		600
G-2	8260	6640	900	600	400	200	38	33	10	5	b.d	b.d	7	8	4100	3600	200	200	1200	800
E-4	7250	8370	900	300	370	190	52	30	10	5	100	b.d	18	10	3800	2000	300	100	1000	300
G-1-C	4220	6260	300	400	240	250	13	13	5	5	100	100	4	3	2800	2700	200	300	300	500
X̄	6927	8605	670	450	366	312	41.5	34.9	6.8	7.1			16.9	13.7	3573	2758	200	200	760	480
S.D	3355	2559	320	170	220	262	25.3	32.3	2.5	2.6			9.8	6.4	734	523	100	200	460	190

JACK PINE

SITE	Ca		K		Mg		Na		B		Cl		F		N		P		S	
	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	71	81
I-4-C	3920	3750	600	200	310	250	46	20	5	b.d	b.d	b.d	14	3	3400	2100	200	900	400	100
J-4	12600	3300	500	200	270	190	21	15	5	b.d	b.d	b.d	26	18	4900	2100	300	200	700	100
K-3-C	2360	2680	500	300	320	250	38	48	b.d	b.d	b.d	b.d	26	16	2800	2300	200	100	200	200
I-9-E	3190	4140	500	200	190	180	15	17	b.d	b.d	b.d	b.d	16	9	4200	3000	300	200	500	300
G-4-C	2620	3170	b.d	300	220	220	8	19	b.d	b.d	b.d	b.d	14	18	2300	3100	200	100	b.d	200
G-8	4670	4940	1500	700	530	360	62	32	b.d	b.d	b.d	b.d	48	28	5200	2600	300	200	400	300
F-7-C	3840	4170	300	300	260	290	8	16	5	5	b.d	b.d	10	28	2100	2700	100	200	b.d	b.d
G-4	2880	2880	600	300	270	170	78	40	b.d	b.d	b.d	b.d	21	12	3900	2700	300	100	300	200
N-3	3360	2870	400	b.d	240	170	21	17	b.d	b.d	b.d	b.d	22	16	4600	2400	300	200	500	200
F-4-C	4330	4570	500	200	210	180	18	18	b.d	b.d	b.d	b.d	17	16	2800	4500	100	300	400	100
G-2	2750	2100	400	b.d	220	140	15	13	b.d	b.d	b.d	b.d	6	4	3100	3300	100	100	200	200
G-1-C	3450	3800	400	200	290	210	16	14	b.d	b.d	b.d	b.d	14	5	3600	2900	200	100	300	100
F-1-C	3680	3750	200	400	230	310	20	34	b.d	b.d	b.d	b.d	4	7	3000	2300	200	200	b.d	200
D-4	2470	2240	500	300	160	130	28	34	5	b.d	b.d	b.d	5	4	3200	2200	100	100	400	200
X̄	4009	3454	510	240	266	218	28.1	24.1					17.4	13.1	3507	2729	200	200	330	180
S.D	2569	851	310	90	88	67	20.8	11.2					11.3	8.3	945	637	100	200	180	70

TABLE 15 continued

WHITE PINE

SITE	Ca		K		Mg		Na		B		Cl		F		N		P		S	
	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
N-6	2500	1810	600	400	150	140	24	14	b.d	b.d	b.d	b.d	16	12	3800	1700	200	100	600	200
I-9-S	2200	2370	800	400	150	120	22	12	b.d	b.d	b.d	b.d	15	10	5100	2700	300	200	400	100
H-9	510	3830	300	400	20	140	13	15	b.d	b.d	b.d	b.d	5	15	3200	3200	200	100	200	300
G-9-E	1830	1650	1000	700	310	180	20	13	5	b.d	b.d	b.d	11	9	3200	2600	200	200	100	100
X̄	1760	2415	670	470	158	145	19.8	13.5					11.8	11.5	3825	2550	200	200	320	170
S.D	877	993	300	150	119	25	4.8	1.3					5.0	2.6	896	624	100	100	220	100
BALSAM FIR																				
J-6		8720		2400		390		24		10		b.d		14	4100			300		200
X̄																				
S.D																				
TAMARACK																				
J-6		4600	500	400		310		24		5	b.d	b.d	12	15	5200	3500	400	200	500	300
M-4	5170	6570		900	470	380	21	18	5	5	b.d	b.d	17	14	5800	3600	400	200		400
X̄		5585		650		345		21		5			14.5	14.5	5500	3550	400	200		350
S.D		1393		350		50		4.2		0			3.5	0.7	424	71	0	0		70
WHITE CEDAR																				
K-6-C	31900	19500	1000	700	290	320	31	32	10	5	200	200	5	11	5700	6800	300	300	900	1100
K-8	27500	9730	400	400	270	160	24	18	10	5	b.d	b.d	19	7	4800	3200	300	200	1100	300
X̄	29700	14615	700	550	280	240	27.5	25.0	10.0	5			12.9	9.0	5250	5000	300	300	1000	700
S.D	3111	6908	420	210	14	113	5.0	9.9	0	0			9.9	2.8	636	2546	0	100	140	570

TABLE 16. Deciduous tree bark non-metal analyses for 1970-71 and 1981. (10 elements, all are plant nutrient elements except for F). Units are micrograms per gram. The sample sites are arranged in order of increasing distance from Thunder Bay city. b.d = below detection limit (B<1.0, Cl<100.0, and F<1.0)

WHITE BIRCH

ELEMENT	Ca		K		Mg		Na		B		Cl		F		N		P		S	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																				
J-6		980		400		200		77		b.d		3200		14		6100		300		700
K-6-C	710	860	2500	500	290	220	37	32	b.d	b.d	1200	2400	8	9	7000	5600	600	300	800	800
K-8	450	1370	400	600	110	150	13	27	b.d	b.d	2100	400	22	27	5200	5900	400	300	200	400
J-3-C	940	510	300	b.d	130	100	16	16	b.d	b.d	1100	1600	12	11	5000	4700	300	300	500	300
J-4	710	710	300	700	140	190	14	20	b.d	b.d	1600	1000	14	23	4100	5000	300	300	700	600
K-3-C	450	550	b.d	300	160	170	21	70	b.d	b.d	1700	1100	27	26	3300	3500	300	300	300	400
I-9-E	860	430	1100	b.d	190	150	26	7	b.d	b.d	1900	2000	17	36	4300	3200	400	200	500	100
I-8-S	610	410	300	b.d	80	80	23	18	b.d	b.d	1300	1200	b.d	22	4600	3500	200	100	300	100
M-4	810	1180	200	1000	140	360	20	29	b.d	b.d	500	400	18	106	4400	3600	200	200	400	200
I-9-S	1020	450		b.d	130	100	35	18	b.d	b.d		700	14	31	4600	3300	300	300		200
H-9	950	1960	400	900	140	260	20	26	b.d	b.d	800	1500	10	10	5700	5600	300	400	300	600
G-8		690		300		210		34		b.d		2200		28		4600		300		400
N-3	23700	1340		300	1640	460	36	25	5	b.d		300	18	70	4600	3500	200	200		200
F-4-C	670	940	b.d	500	120	150	21	26	b.d	b.d	2100	1500	38	13	4500	5000	200	200	200	300
N-2-C	1040	1380		500	390	430	48	36	5	b.d		1300	22	21	4000	3200	400	200		b.d
E-4	320	710	b.d	b.d	130	130	19	18	b.d	b.d	1900	1300	18	63	3800	4100	300	200	200	200
G-1-C	100	1020	300	600	20	160	14	20	b.d	b.d	1000	1500		12	4800	5900	200	300	400	900
F-1-C	920	1090	300	600	240	410	42	18	b.d	b.d	2500	1300	8	10	4800	6100	300	400	300	400
D-4	1010	800	300	400	160	160	39	42	10	b.d	1200	2100	9	5	4100	4300	200	200	300	300
X	2075	915	500	543	248	215	26.1	29.4	5.3		1490	1421	16.1	28.3	4635	4563	300	263	390	374
S.D.	5579	962	620	731	368	206	11.0	17.9			570	762	8.5	26.4	825	1045	100	123	180	231

TABLE 16. continued
TREMBLING ASPEN

ELEMENT	Ca		K		Mg		Na		B		Cl		F		N		P		S	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																				
K-6-C	24100	13600	1800	1500	570	650	20	20	10	10	b.d	b.d	7	4	8700	5600	600	400	1600	600
K-8	9560	12400	3300	5200	400	970	18	36	10	15	b.d	b.d	6	12	4400	11700	300	1000	500	700
I-4-C		16300		3400		1020		41		20		b.d	25	9	8600	5000	1000	400		800
J-3-C	7680	9240	2500	6500	490	790	16	18	15	15	b.d	b.d	20	7	4100	4100	300	400	700	300
J-4	9250	8110	4000	6400	830	910	10	15	15	10	b.d	b.d	22	12	4100	3400	400	300	500	300
K-3-C	8300	10300	7800	3000	730	1130	25	36	20	20	b.d	b.d	14	13	2700	4200	200	300	200	400
I-9-E		12400		3200		940		15		15		b.d	37	8	6400	4000	600	400		400
N-6	10000	10400	1900	800	720	440	48	17	15	15	b.d	b.d	26	15	7400	4100	700	200	1700	900
I-9-S	11200	13100		3500	790	1020	51	14	15	20		b.d	22	15	5100	5000	600	400		500
G-4-C		15300	5600	1800		970		58		20	b.d	b.d		19	8600	6500	900	700	1100	1300
G-9-E	12260		3200		1220		13		15		b.d		6		4000		200		400	
F-7-C	10700	10600	4600	4800	580	700	14	16	10	15	b.d	b.d	7	5	3300	4000	200	300	400	300
G-4	10000	12500	3500	2700	1040	1440	12	22	10	15	b.d	b.d	10	11	5000	3500	400	200	200	400
F-4-C	13510	13410	1500	3300	700	1310	11	31	15	15	b.d	b.d	4	12	5300	6400	300	400	600	400
G-2	12800	14800	500	1400	790	920	11	26	15	15	b.d	b.d	7	12	3600	8500	100	400	500	1000
E-4		9340		2200		570		11		15		b.d	21	12	4600	2700	400	100		300
F-1-C		9470	4300	3600		830		90		15	b.d	b.d		7	9300	4400	900	400	1000	500
D-4		12610	4300	900		900		17		15	b.d	b.d		4	5700	4300	400	300	900	500
$\overline{X}$	11613	11993	3490	3190	738	912	20.8	28.4	13.8	15.6			15.6	10.4	5606	5141	500	400	740	560
S.D.	4304	2339	1870	1740	227	249	14.1	20.1	3.1	3.0			9.9	4.2	2073	2188	300	200	470	290

TABLE 16 continued

BALSAM POPLAR

ELEMENT	Ca		K		Mg		Na		B		Cl		F		N		P		S	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																				
I-4-C		16100	2700	1400		1700		24		15	b.d	b.d	52	4	8300	7300	900	500	1300	1100
I-8-S		20800		3400		2540		44		20		b.d		6		5800		400		800
M-4	14700	15800	1600	2100	900	1110	12	30	15	15	b.d	b.d	12	14	3200	3200	200	300	600	400
G-4-C		14200	2900	1700		1340		23		15	b.d	b.d	44	15	9000	6200	900	400	1200	700
H-9		26500	2000	2000		2030		24		15	b.d	b.d		4	8600	5200	900	400	1200	600
G-9-E		7070		1900		1210		24		10		b.d		10		5100		300		700
G-8	15790	15250	1000	1800	1000	1460	12	49	15	15	b.d	b.d	18	25	4300	5000	200	300	400	600
F-7-C	14500	17300	2300	1900	2020	1770	41	17	15	15	b.d	b.d	25	14	6000	4600	400	200	800	400
G-4	13500		2200		1750		61		15		b.d		20		4800		400		600	
N-2-C	13100	14800	4300	1500	3780	1500	107	24	15	15	b.d	b.d	103	17	6000	4100	700	300	1000	600
G-2	15800	18500	1800	3200	1470	3720	18	61	20	15	b.d	b.d	8	7	5500	5200	300	300	500	500
$\overline{X}$	14565	16632	2311	2090	1820	1838	41.8	32.0	15.8	15			35.3	11.6	6189	5170	544	300	844	640
S.D.	5753	4970	917	670	1675	784	38.6	14.3	3.5	2.4			29.4	6.7	2111	1125	269	100	320	210

BLACK ASH

ELEMENT	Ca		K		Mg		Na		B		Cl		F		N		P		S	
YEAR	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
SITE																				
J-6		18600		1300		1450		26		25		b.d		17		12400		500		800
I-8-S	22300	24800	8900	2400	2180	1090	97	43	40	30	200	b.d	58	4	14700	10000	1400	600	3800	900
N-3	15700	17100	1900	1900	1470	1180	44	16	15	15	b.d	b.d	26	14	11700	7700	800	500	500	800
$\overline{X}$	19000	20167	5400	1870	1825	1240	70.5	28.3	27.5	23.3	150		42	11.7	13200	10033	1100	500	2150	830
S.D.	4667	4082	4950	550	502	187	37.5	13.7	17.7	7.6	70		22.6	6.8	2121	2350	400	100	2330	60

TABLE 17. Paired "t"-test levels of significance between 1970 and 1981 conifer bark samples. % = percent change since 1970. Values are in micrograms per gram. N.S = no significant differences.

		White Spruce -13 (n=17)				Black Spruce 9- (n=11)				Jack Pine 13- (n=14)				White Pine (n=4)				Tamarack (n=2)	White Cedar (n=2)
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	$\bar{X}$
Cu	70	5.9	1.6	-3	N.S	4.7	1.6	-26	N.S	4.9	1.6	-31	0.010	3.3	1.3	-9	N.S	6.0	7.0
	81	5.7	1.8			3.5	1.4			3.4	0.7			3.0	1.8			5.0	7.5
Cd	70	0.20	0.09	0	N.S	0.19	0.10	-5	N.S	0.38	0.19	-21	N.S	0.23	0.05	9	N.S	0.30	0.50
	81	0.20	0.14			0.18	0.08			0.30	0.18			0.25	0.13			0.40	0.50
Cr	70	2.1	1.4	-5	N.S	2.6	2.1	-31	N.S	2.5	2.3	4	N.S	1.0	0.0	0	N.S	13.0	6.5
	81	2.0	1.7			1.8	1.8			2.6	1.9			1.0	0.0			8.0	5.0
Fe	70	275.0	185.4	38	N.S	472.7	72.1	-52	0.010	717.9	987.9	-46	N.S	387.5	340.0	-36	N.S	750.0	425.0
	81	379.4	396.1			227.3	30.4			385.7	408.8			250.0	147.2			450.0	500.0
Hg	70	0.15	0.08	-33	N.S	0.20	0.07	-40	0.010	0.13	0.05	-46	0.001	0.11	0.10	-46	N.S	0.20	0.20
	81	0.10	0.07			0.12	0.04			0.07	0.02			0.06	0.03			0.08	0.26
Mn	70	130.5	66.6	-6	N.S	156.6	106.0	14	N.S	50.6	25.0	-5	N.S	76.0	118.6	-66	N.S	251.0	30.0
	81	122.6	55.6			179.1	67.2			47.9	20.9			25.8	4.6			250.0	84.5
Mo	70	b.d				b.d				b.d				b.d				b.d	b.d
	81	b.d				b.d				b.d				b.d				b.d	0.3
Ni	70	1.2	0.6	42	N.S	1.9	1.0	-5	N.S	2.2	1.4	0	N.S	1.3	0.5	0	N.S	7.0	4.5
	81	1.7	1.2			1.8	1.2			2.2	1.1			1.3	0.5			6.0	4.0
Pb	70	3.8	2.8	11	N.S	4.5	2.3	-11	N.S	5.1	3.4	-33	N.S	2.3	1.3	196	N.S	4.0	8.5
	81	4.2	2.6			4.0	1.5			3.4	1.8			6.8	9.5			6.0	12.0
Zn	70	83.1	34.7	11	N.S	55.5	22.4	20	N.S	37.6	12.7	-17	N.S	36.3	8.1	-20	N.S	60.0	51.5
	81	92.4	30.2			66.4	34.8			31.2	11.0			29.0	7.4			64.0	63.5
Al	70	220.4	182.0	-1	N.S	362.7	177.8	-53	0.010	680.7	271.5	-26	0.050	370.0	223.3	-25	N.S	350.0	315.0
	81	219.4	177.0			170.0	112.1			502.9	150.1			277.5	77.2			155.0	355.0
As	70	0.41	0.66	-59	N.S	0.38	0.23	-66	0.010	.37	.51	16	N.S	0.15	0.11	-20	N.S	0.40	0.14
	81	0.17	0.18			0.13	0.11			.43	1.27			0.12	0.01			0.12	0.16
pH	70	3.8	0.46	11	N.S	3.4	0.19	6	N.S	3.6	0.79	-6	N.S	3.2	0.27	0	N.S	3.7	4.4
	81	4.2	0.56			3.6	0.28			3.4	0.14			3.2	0.25			3.7	3.7

TABLE 17 continued

		White Spruce 13- (n=17)				Black Spruce 9- (n=11)				Jack Pine 13- (n=14)				White Pine (n=4)				Tamarack (n=2)	White Cedar (n=2)
Element	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	$\bar{X}$
Ca	70	13706.2	5577.3	-2	N.S	6927.3	3354.7	-21	N.S	4008.6	2568.6	-14	N.S	1760.0	877.2	37	N.S	5170.0	29700.0
	81	13387.1	6387.1			8405.5	2584.2			3454.3	850.9			2415.0	992.6			5585.0	14615.0
K	70	1386	990	-23	N.S	667	320	-32	N.S	507	310	-54	0.010	675	300	-30	N.S	500	700
	81	1065	520			455	180			236	90			475	150			650	550
Mg	70	316.2	175.2	16	N.S	366.4	219.6	-12	N.S	265.7	88.4	-18	N.S	157.5	118.7	-8	N.S	470.0	280.0
	81	368.2	149.7			321.8	272.0			217.9	66.8			145.0	25.2			345.0	240.0
Na	70	30.0	22.6	20	N.S	41.5	25.3	-14	N.S	28.1	20.8	-14	N.S	19.8	4.8	-32	0.050	21.0	27.5
	81	35.9	30.0			35.7	33.7			24.1	11.2			13.5	1.3			21.0	25.0
B	70	7.46	2.50	3	N.S	6.82	2.52	0	N.S	5.00	0.00	0	N.S	5.00	0.00	0	N.S	5.00	10.00
	81	7.65	3.12			6.82	2.52			5.00	0.00			5.00	0.00			5.00	5.00
Cl	70	100	0.0	0	N.S	100	0.0	18	N.S	100	0.0	0	N.S	100	0.0	0	N.S	100	150
	81	100	0.0			118	4.0			100	0.0			100	0.0			100	150
F	70	16.4	16.1	-34	N.S	16.9	9.8	-16	N.S	17.4	11.3	-25	N.S	11.8	5.0	-3	N.S	14.5	12.0
	81	10.8	16.8			14.2	6.4			13.1	8.3			11.5	2.6			14.5	9.0
N	70	3905.9	1344	-16	N.S	3572.7	734	-24	0.010	3507.1	945	-22	0.050	3825	896	-33	N.S	5500	5250.0
	81	3288.2	1258			2718.2	529			2728.6	637			2550	624			3550	5000.0
P	70	0.3	0.1	-33	N.S	0.2	0.1	0	N.S	0.2	0.1	0	N.S	0.2	0.1	0	N.S	0.4	0.3
	81	0.2	0.1			0.2	0.2			0.2	0.2			0.2	0.1			0.2	0.3
S	70	557	390	-30	N.S	756	460	-40	N.S	329	180	-46	0.010	325	220	-46	N.S	500	1000
	81	388	270			455	160			179	70			175	100			350	700

TABLE 18. Paired "t" - test levels of significance between 1970 and 1981 deciduous bark samples. % = percent change since 1970. Values are in micrograms per gram. N.S = no significant differences.

		White Birch 14- (n=17)				Trembling Aspen 11- (n=17)				Balsam Poplar 6- (n=9)				Black Ash			
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Cu	70	6.4	1.7	13	N.S	8.0	1.8	-20	0.050	9.8	5.7	-28	N.S	16.5	2.1	-12	N.S
	81	7.2	4.0			6.4	2.0			7.1	1.2			14.5	5.0		
Cd	70	0.32	0.15	31	N.S	0.81	0.35	37	N.S	1.20	0.82	-16	N.S	0.40	0.28	-50	N.S
	81	0.42	0.33			1.11	0.59			1.01	0.31			0.20	0.14		
Cr	70	3.9	5.0	-13	N.S	2.5	2.3	4	N.S	4.5	5.4	-51	N.S	5.5	6.4	-82	N.S
	81	3.4	4.5			2.6	2.6			2.2	1.9			1.0	0.0		
Fe	70	274.7	205.2	13	N.S	204.5	145.7	11	N.S	1016.7	1042.9	-61	N.S	725.0	176.8	-72	N.S
	81	310.3	212.3			227.8	209.0			400.0	449.3			200.0	0.0		
Hg	70	0.06	0.05	-50	N.S	0.07	0.08	-57	N.S	0.08	0.04	-63	0.010	0.17	0.00	-67	N.S
	81	0.03	0.02			0.03	0.03			0.03	0.02			0.07	0.01		
Mn	70	314.9	215.1	8	N.S	41.4	27.8	67	N.S	67.0	49.7	-33	N.S	153.5	128.0	-27	N.S
	81	341.4	238.8			69.3	48.5			44.6	23.3			112.5	82.7		
Mo	70	0.8	1.1			0.5	0.0			0.6	0.2			0.5	0.0		
	81	0.5	0.0			0.5	0.0			0.5	0.0			0.5	0.0		
Ni	70	2.4	2.5	0	N.S	1.6	1.1	31	N.S	3.0	3.2	-40	N.S	3.0	2.8	-50	N.S
	81	2.4	2.0			2.1	1.9			1.8	1.1			1.5	0.7		
Pb	70	12.2	7.1	-28	N.S	4.3	2.2	21	N.S	5.5	2.4	4	N.S	9.5	5.0	-37	N.S
	81	8.8	3.8			5.2	3.2			5.7	3.2			6.0	0.0		
Zn	70	107.5	58.8	-0.2	N.S	119.6	36.3	27	N.S	228.8	151.5	-19	N.S	45.5	10.6	-19	N.S
	81	107.3	66.9			151.7	52.6			186.0	40.5			37.0	15.6		
Al	70	173.8	118.5	10	N.S	188.2	171.2	-5	N.S	550.0	690.1	-54	N.S	830.0	127.3	-75	0.050
	81	191.2	140.6			178.2	173.2			252.2	223.3			205.0	21.2		
As	70	0.40	0.15	-48	0.001	0.16	0.18	-50	N.S	0.34	0.38	-68	N.S	0.73	0.54	-90	N.S
	81	0.21	0.13			0.08	0.08			0.11	0.14			0.07	0.01		
pH	70	3.8	0.31	5	N.S	4.6	0.53	11	N.S	5.0	0.36	8	N.S	6.4	0.0	6	N.S
	81	4.0	0.35			5.1	0.63			5.4	1.05			6.8	0.5		

TABLE 18 continued

		White Birch 14- (n=17)				Trembling Aspen 11- (n=17)				Balsam Poplar 6- (n=9)				Black Ash (n=2)			
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Ca	70	2074.7	5579.2	-56	N.S	11544.5	4509.4	4	N.S	17478.3	6689.1	-8	N.S	19000.0	4666.9	10	N.S
	81	924.1	426.5			11992.9	2339.3			16168.9	5037.0			20950.0	5444.7		
K	70	500	620	-7	N.S	3508	1940	-9	N.S	2433	990	-20	N.S	5400	4950	-60	N.S
	81	465	250			3188	1740			1944	520			2150	350		
Mg	70	247.6	368.4	-13	N.S	694.5	177.5	31	0.050	2215.0	1405.5	-21	N.S	1825.0	502.0	-38	N.S
	81	216.5	122.6			912.4	248.8			1760.0	788.8			1135.0	63.6		
Na	70	26.1	11.0	1	N.S	21.5	14.6	32	N.S	36.8	36.2	-17	N.S	70.5	37.5	-58	N.S
	81	26.4	14.0			28.4	20.1			30.7	14.5			29.5	19.1		
B	70	5.29	1.21	6	N.S	13.64	3.23	14	N.S	20.00	10.00	-28	N.S	27.50	17.68	-18	N.S
	81	5.00	0.00			15.59	3.00			14.44	1.67			22.50	10.61		
Cl	70	1493	570	-15	N.S	100	0.0	0	N.S	b.d				150	70	-33	N.S
	81	1271	590			100	0.0			b.d				100	0		
F	70	16.1	8.5	81	N.S	16.3	9.8	-36	0.050	37.6	30.7	-68	0.050	42.0	22.6	-79	N.S
	81	29.1	26.9			10.4	4.2			12.2	6.8			9.0	7.1		
N	70	4635.3	825.0	-4	N.S	5700.0	2.097	-10	N.S	6722.2	2244	-24	N.S	13200.0	2.1	-33	N.S
	81	4470.6	1068.0			5141.2	2.188			5100.0	1169			8850.0	1.6		
P	70	0.3	0.1	0	N.S	0.5	0.3	-20	N.S	0.6	0.3	-50	0.050	1.1	0.4	-46	N.S
	81	0.3	0.1			0.4	0.2			0.3	0.1			0.6	0.1		
S	70	368	180	-2	N.S	762	480	-26	N.S	911	340	-32	0.050	2150	2330	-61	N.S
	81	359	240			565	290			622	210			850	70		

TABLE 19. Paired "t"- test levels of significance between 1970 and 1981 combined bark samples. % = percent change since 1970. Values are in micrograms per gram. N.S. = no significant differences.

		All Deciduous Species (n=34-43)				All Conifer Species (n=37-42)				Deciduous and Conifers combined (n=80-95)			
Elements	Year	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Cu	70	7.5	3.0	-8	N.S	5.2	1.6	-17	0.05	6.4	3.1	-11	N.S
	81	6.9	2.8			4.3	1.8			5.7	3.0		
Cd	70	0.63	0.52	30	N.S	0.26	0.16	-12	N.S	0.43	0.40	16	N.S
	81	0.82	0.54			0.23	0.15			0.50	0.48		
Cr	70	3.6	4.3	-22	N.S	2.4	1.9	-13	N.S	3.1	3.5	-16	N.S
	81	2.8	3.4			2.1	1.8			2.6	2.9		
Fe	70	382.9	530.4	-23	N.S	495.4	636.8	-31	N.S	449.9	561.4	-29	N.S
	81	296.4	276.7			341.7	348.5			320.0	303.8		
Hg	70	0.07	0.06	-57	0.001	0.15	0.07	-33	0.001	0.12	0.08	-42	0.001
	81	0.03	0.02			0.10	0.05			0.07	0.06		
Mn	70	182.6	202.8	-6	N.S	108.6	82.6	4	N.S	139.0	150.9	-0.7	N.S
	81	171.7	205.2			112.5	71.4			138.0	151.7		
Mo	70	0.7	0.8			0.5	0			0.6	0.5		
	81	0.5	0.0			0.5	0			0.5	0.0		
Ni	70	2.3	2.3	-4.5	N.S	1.8	1.2	6	N.S	2.1	1.9	0	N.S
	81	2.2	1.8			1.9	1.1			2.1	1.7		
Pb	70	8.5	6.4	-21	N.S	4.5	2.9	-13	N.S	6.3	5.2	-13	N.S
	81	6.7	3.8			3.9	2.1			5.5	3.9		
Zn	70	132.8	87.3	6	N.S	58.3	31.0	12	N.S	88.0	71.3	11	N.S
	81	141.3	63.3			65.2	37.3			97.5	63.9		
Al	70	244.9	329.3	-19	N.S	431.2	292.8	-30	0.05	355.9	316.8	-30	0.01
	81	198.8	171.0			301.0	209.1			249.8	190.7		
As	70	0.30	0.25	-53	0.001	0.39	0.51	-36	N.S	0.34	0.39	-44	0.05
	81	0.14	0.13			0.25	0.74			0.19	0.50		
pH	70	4.4	0.63	7	N.S	3.7	0.55	0	N.S	4.0	0.76	5	N.S
	81	4.7	0.89			3.8	0.53			4.2	0.92		

TABLE 19 continued

Elements	Year	All Deciduous Species (n=34-43)				All Conifer Species (n=37-42)				Deciduous and Conifers combined (n=80-95)			
		$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P	$\bar{X}$	S.D	%	P
Ca	70	7860.0	8163.7	8	N.S	8171.1	5764.4	12	N.S	8485.8	7740.1	5	N.S
	81	8490.0	6910.7			9176.2	6354.2			8868.1	6763.3		
K	70	2069.0	1860.0	-11	N.S	878.0	760.0	-18	N.S	1493.0	1680.0	-19	N.S
	81	1851.0	1650.0			629.0	500.0			1206.0	1320.0		
Mg	70	739.4	946.4	10	N.S	312.1	165.6	-2	N.S	522.3	691.0	5	N.S
	81	814.7	698.6			306.0	180.4			546.3	555.3		
Na	70	26.5	18.7	6	N.S	32.7	22.9	-2	N.S	30.1	21.5	-4	N.S
	81	28.1	16.5			31.9	26.3			29.0	21.1		
B	70	10.59	7.26	5	N.S	6.37	2.22	3	N.S	8.67	6.46	2	N.S
	81	11.16	5.44			6.55	2.59			8.84	5.23		
Cl	70	642.0	770.0	-12	N.S	100.0	0	5	N.S	340.0	570.0	-8	N.S
	81	563.0	690.0			105.0	20.0			313.0	510.0		
F	70	20.7	17.9	-12	N.S	16.9	12.7	-26	N.S	18.7	15.4	-20	N.S
	81	18.2	19.3			12.5	7.2			14.9	14.1		
N	70	5493.0	1880.0	-11	N.S	3685.7	1074.0	-20	0.001	4781.1	2119.0	-17	0.01
	81	4867.4	1620.0			2952.4	945.0			3982.1	1767.0		
P	70	0.4	0.3	-25	0.05	0.2	0.1	0	N.S	0.4	0.2	-25	0.01
	81	0.3	0.2			0.2	0.2			0.3	0.2		
S	70	653.0	410.0	-24	0.05	519.0	380.0	-35	0.01	620.0	530.0	-32	0.001
	81	495.0	270.0			336.0	220.0			420.0	270.0		

TABLE 20. Bark samples - white spruce - element inter-relationships based on Pearson correlation coefficients. Significance of correlations: 1 ≤0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city; ALT = Altitude; D1 = Distance to Lake Superior

		D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
					70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1			3	3				2																				1*																		1*		
ALT				2				2										1*	1*	1*		1*						2*																		1*	1*	
D2																										1*									1				1					1*		1*		
Fe	'70								2		1		3																2					1	1				1				1					
	'81									1				3		2										1				1		1										1						
Mn	'70							1		1								1		2	2	2																										
	'81																																															
P	'70										3		3		3				2										3		2				1						1*		2				1	1
	'81											3	1*	2								2				1						2									1		2*			3		1*
N	'70												1		3				1								1		2		3														3			
	'81													1				1		1		3				1		1				1									1	1	2*			3		
Al	'70																		1										3		1			2	2				2				2		1			
	'81																					1			2	1						2								3	1	1				1		
As	'70																														2																	
	'81																												2	3																		
B	'70																	2																	1												2	
	'81																			2	2	2														1						1				1	2	
Ca	'70																			2	1								1																		3	1
	'81																				3	3						1														1				1	1	
Cd	'70																					1																				1					1	
	'81																									1		2														2				2		
Cl	'70																																															
	'81																																															
Cr	'70																									2	1*					3									3					2		2*
	'81																															2									2					3		1*
Cu	'70																											1				1*	1								1*			1*				
	'81																													1*																1		
F	'70																													3	1				2								3					1
	'81																																															
Hg	'70																																										1		3			
	'81																																								3					3		2*
K	'70																																						1					1*	1			
	'81																																		3	1			3									
Mg	'70																																			1			2								1	
	'81																																						1	2		2						2
Mo	'70																																															
	'81																																															
Na	'70																																												1			
	'81																																									1						
Ni	'70																																													2		3*
	'81																																											2				
Pb	'70																																															
	'81																																															
S	'70																																															
	'81																																															1*
Zn	'70																																															
	'81																																															

TABLE 21. Bark samples - black spruce - element inter-relationships based on Pearson correlation coefficients. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city; ALT = Altitude; D1 = Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		2	1	1*								1*																1*	2*													1*					1*
ALT				1*		1	1*												1*								1*	1*	3*																		2*
D2																																															
'70 Fe						1*	1*	1*				3*							1							1	2	1	1	1	2*	1		1													2*
'81 Fe												1	3										3				1						1	1	2			1	1	1					2		
'70 Mn							1										1*				1																										
'81 Mn																			1*				1			1*	1*		1		1	2*						2*									1
'70 P										1*		1*							1											1								1									1
'81 P										1				2*																1*									3					1*			
'70 N														1*		1		1								1				3		1							1*					1		2	
'81 N																															1														1		
'70 Al													1						1				2				1	3	1		1			1	2							1					2
'81 Al																							2				1	1					1	2	3							1			1		
'70 As																																2												2			
'81 As																																															
'70 B																		1														2	1	2				1									
'81 B																					1*		1				1						1	1	1				1								
'70 Ca																										1				1		1	1	1				1								2	
'81 Ca																											1	2	2			1	1	2	1			2									3
'70 Cd																					1																										
'81 Cd																																															
'70 Cl																																															
'81 Cl																											1	1						1	2				3			1					
'70 Cr																																								3							
'81 Cr																																									3				1		
'70 Cu																																1						2					1*				
'81 Cu																												1	1		1*		2	3	3												2
'70 F																													3		1*				3	2						2					3
'81 F																															3				1							1					2
'70 Hg																																1												2		1	1
'81 Hg																																															
'70 K																																		3				3									
'81 K																																		3	2											1	2
'70 Mg																																			3												2
'81 Mg																																															3
'70 Mo																																															
'81 Mo																																															
'70 Na																																															1
'81 Na																																															
'70 Ni																																															
'81 Ni																																												1			
'70 Pb																																															
'81 Pb																																															
'70 S																																															
'81 S																																															
'70 Zn																																															
'81 Zn																																															

TABLE 22 . Combined bark samples - jack pine - element inter-relationships based on Pearson correlation coefficients for 1970 and 1981. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city. ALT = Altitude. D1 = Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		2	3		1*			1*												2*	2*							1*														1*				3*	2*
ALT			1																		3*				2*		2*												1*							1*	3*
D2								1*												1*						1*		1*														1*				2*	1*
'70 Fe					3					1		3	1	3	3				1	1	1			1		1		3	1			3	2*	3	2			1							1		
'81 Fe												3	1	3	2									1		1		3	1			3	2*		2			1		1							
'70 Mn							1																	1*														1*	1*	1*							
'81 Mn																			1		1						2			1*				3				1*	1*								2
'70 P										3		1		1						3	1				1	1		2			1										1	2		1		2	
'81 P																																															
'70 N												1		2	1			1		3						1		2		2	1	2	2*	1								1		3		1	
'81 N																											1																				
'70 Al													3	3	3				1					1		3		3	1			3	1*	3	1			2	1			2					
'81 Al														1	1				1							2		2	1					1	1				1	1		1					
'70 As															3					2				1		1		3	1	1		3	2*	3	1			2									
'81 As																			1	1	1			1				3	1			3	2*	3	2			1							1		
'70 B																																															
'81 B																																															
'70 Ca																				1							1*				1											2		2		1	
'81 Ca																					2								1					1	2												2
'70 Cd																					2							1	1		1	1	2	1								1		2		3	1
'81 Cd																											1	1					1*								1				1	1	3
'70 Cl																																															
'81 Cl																																															
'70 Cr																										1						1		2	1			3	1	3							
'81 Cr																																									2						
'70 Cu																												1				1		1				2	1	2		2	1				
'81 Cu																														2*																	2
'70 F																													2	1		3	2*	3				1				1					
'81 F																																		1	1												
'70 Hg																																	1*	1				1						1			
'81 Hg																																										2				1	
'70 K																																	3*	3				2									
'81 K																																		2*										1*			
'70 Mg																																			2*			1		1							
'81 Mg																																								1							
'70 Mo																																															
'81 Mo																																															
'70 Na																																							2	2							
'81 Na																																								2			1			1*	
'70 Ni																																									1						
'81 Ni																																													2		1
'70 Pb																																												1		2	
'81 Pb																																															
'70 S																																														2	
'81 S																																															
'70 Zn																																															2
'81 Zn																																															

TABLE 23 . Bark samples - white birch - element inter-relationships based on Pearson correlation coefficients for 1970 and 1981. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city. ALT - Altitude. D1 = Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		3	3					1*								1				2*	2*																										1*
ALT			1					2*												1*	2*											2*															1*
D2								1*						1*		1				1*	1*											1*												1*			
'70 Fe					2			2		2		3	1	1									1	1		1						3						2		2		2		1			
'81 Fe									2		2	1	3																1*																		
'70 Mn																						2						1															2				1*
'81 Mn																							1																								
'70 P										1		2																				3										2		1			
'81 P											2		2		1										1*																1*				2		
'70 N											2	2		3	1						1										1	2								1		2			1		
'81 N													2		3														1*	1	2		1												3		
'70 Al													1											2		1						2		1	1			3		3		3		1			
'81 Al																						1													1												
'70 As																				1	2	1*					1*	1*				2							1*	1		3		3			
'81 As																		1*								1*				1	3			1*				2*					1		3		
'70 B																																															
'81 B																																															
'70 Ca																							1*	3	1									3	1	3				3	1	1					
'81 Ca																															1		3		2												
'70 Cd																					3												1*		1*							1					1
'81 Cd																												1*				1										1					3
'70 Cl																																														1	
'81 Cl																													2*			1															
'70 Cr																									1							3		3	1	3		1		3	1	2		1		1*	
'81 Cr																																		1		1				1	3						
'70 Cu																														1*	1*											1					
'81 Cu																																							3				1				
'70 F																																											1				
'81 F																																													1*		
'70 Hg																															3					1									1		
'81 Hg																																													2		
'70 K																																		2						3		3		2			
'81 K																																			1										1		
'70 Mg																																			2	3				3	1	1					
'81 Mg																																				1		1		1							
'70 Mo																																								2	1						
'81 Mo																																															
'70 Na																																								1							
'81 Na																																											2				
'70 Ni																																										3		1		1*	
'81 Ni																																															
'70 Pb																																												2		1*	
'81 Pb																																															
'70 S																																															
'81 S																																															
'70 Zn																																															1
'81 Zn																																															

TABLE 24 . Bark samples - trembling aspen - element inter-relationships based on Pearson correlation coefficients for 1970 and 1981. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay. ALT = Altitude. D1 = Distance to Lake Superior.

		D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
					70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1			3	3	1*			3					1*	1																									1*			1	1*		1*			
ALT					2*			1					1*													1*					1*								1*			1*	3*		1*			
D2								2																											1													
Fe	'70								2		2		3						1												3	1				1*			2				1		3			
	'81							2	1		2			3	2	3			1						2			3												3	2			3		1	1	
Mn	'70																		2		1						3																				3	
	'81													3														1												1	2			1				
P	'70										3		3		3														1		2								2	1					2	1		
	'81											3										3				1									1*						1		2			1		1
N	'70												1	1	3				2		2										2	1								1		1		1	3	1	1	
	'81																			1		2			2	1			1*												2		1			1		1
Al	'70																												1		3	1				1*			3						3			
	'81														1										2			2												3	2			3		1		
As	'70															1										1														1		3			1			
	'81																1*								1				1*										1*		1							
B	'70																	1*								1*				1												1*						
	'81																			1		1								1			1														1*	
Ca	'70																			1	1				1	1	1															1			1		3	
	'81																				2	1			1									1*							1			1		2		2
Cd	'70																										1		1*														1					
	'81																													1													1			1		3
Cl	'70																																															
	'81																																															
Cr	'70																									2		1		1											3	1		1		2		
	'81																																								1	3	1					
Cu	'70																																														1	
	'81																																						1*	2	1			2		1		1
F	'70																																						1									
	'81																																													1		1
Hg	'70																															3		1*		2*			2						3	1		1
	'81																																			2*									3	2		
K	'70																																														1*	
	'81																																												1*	1*		
Mg	'70																																															
	'81																																												2*			1
Mo	'70																																															
	'81																																															
Na	'70																																												1			
	'81																																											1				
Ni	'70																																									1		1		2		1
	'81																																										1					
Pb	'70																																															
	'81																																													3	1	
S	'70																																														1	
	'81																																															1
Zn	'70																																															
	'81																																															

TABLE 25 . Bark samples - balsam poplar - element inter-relationships based on Pearson correlation coefficients for 1970 and 1981. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city. ALT = Altitude. D1 = Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		2																			1*			1*									1		1				1								
ALT												1*									1*			1*				1*				1*								2*							
D2							2		1*																2*																2*				2*		
'70 Fe												1																		1		1						1	1*					1			
'81													3	1		1	3*	2	1*	1																1						1				1	
'70 Mn										1																1				2																	
'81																									1*																1*						
'70 P									1	3						1		1		2						2				2		1		3		1			1*			1		3	1	1	
'81											2																																	1	1		
'70 N											1					1		1		1						2				2				1		1						1		3	1	1	
'81																																													1		
'70 Al																					1			1				3				2		1				3		1							
'81														1		2	3*	2	2*	1	2*															2						1				2	
'70 As																	1*			2						2				1		1		2		1						1				1	
'81																													1																		
'70 B																	3*	3	1*	1						1										3						1				3	
'81																		3*	1	2*						1*										3*						2*				3*	
'70 Ca																			3*	1						1										3						1				2	
'81																				3*							1									2*						2*	1*			2*	
'70 Cd																										1								1		2						2		1		2	
'81																								1				2				1			1*			1		1							
'70 Cl																																															
'81																																															
'70 Cr																												1										1		3							
'81																																									3						
'70 Cu																														2				1		1				1		2		2		1	
'81																																							1								
'70 F																																2	1*	1				3		1							
'81																																															
'70 Hg																																		1					1*			1		2			
'81																																															1*
'70 K																																		2				1						1			
'81																																							1								
'70 Mg																																												2		1	
'81																																											1*				
'70 Mo																																										2				3	
'81																																															
'70 Na																																								1							
'81																																												1*			
'70 Ni																																															
'81																																															
'70 Pb																																												1		2	
'81																																															
'70 S																																													1		
'81																																															
'70 Zn																																															
'81																																															

TABLE 26 . Pearson correlation coefficients inter-relationships for the combined bark sample of white spruce, black spruce, and jack pine. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city; ALT = Altitude; D1 = Distance to Lake Superior.

		D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr	
					70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1			3	3																1*	1*	1*				
ALT				2										1*				1*	1*	2*		1*				
D2										1*												1*				
Fe	'70					3			1		2		3	2	3	3					2	1			1	
	'81												2	3		3						1			1	
Mn	'70							3					3*	1*			3		3	2						
	'81												2*	2*						1	1*					
P	'70										3		1		3				1		3					
	'81																							1		
N	'70												2		3				1		2					
	'81												1*					2		3		1				1
Al	'70													3	3	3			1*	2*	3	1				
	'81															1			1*	1*	3	2				
As	'70															3					2				1	
	'81																				2	2			1	
B	'70																	3	3	2						
	'81																		3	3				1		
Ca	'70																			3						
	'81																									
Cd	'70																					3				
	'81																									1
Cl	'70																									
	'81																									
Cr	'70																									1
	'81																									
Cu	'70																									
	'81																									
F	'70																									
	'81																									
Hg	'70																									
	'81																									
K	'70																									
	'81																									
Mg	'70																									
	'81																									
Mo	'70																									
	'81																									
Na	'70																									
	'81																									
Ni	'70																									
	'81																									
Pb	'70																									
	'81																									
S	'70																									
	'81																									
Zn	'70																									
	'81																									

		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
		70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		1*	2*	1*	1*													1*			1*	1*	1*
ALT			3*								1*								1*		2*	2*	1*
D2		1*																	1				
Fe	'70			3	3					1				2		1							
	'81			2	2		1				1				1	1	2						
Mn	'70						1														2	2	
	'81														1						1		1
P	'70	2		3		3		2		2	1			3				3		1		1	1
	'81														1								
N	'70	2		3		3		3		1				2				1		3		1	2
	'81		3	1*			2											2*	1		3		
Al	'70		1*	3	2		1*		1*	1				1		2		3		1*	1*		
	'81				1				1*							2	2			2*		1*	2*
As	'70			3		3								1		1		1		1			
	'81			3	2											1							
B	'70	1	1					1	3	3	2			1							1	3	3
	'81	1	3						2	2	3				2						2	3	2
Ca	'70	2	3					1	3	1	2					1*				1	1	3	3
	'81	2	3					1	3		3					1*					3	3	3
Cd	'70			2	1				2*									2					
	'81								1*								3						
Cl	'70																						
	'81									2	3				3						1		
Cr	'70						1									3	1						
	'81						1										3				2		
Cu	'70		3					3	1					2								2	1
	'81							2	3	1	3					1*					2	3	3
F	'70				3	2				3	2			2				2					1
	'81									2	1							2					
Hg	'70									1				1				2		3			
	'81																		1		3		
K	'70								3	1	2			2						2			3
	'81									2	3			1	1	1*						3	3
Mg	'70										3			3								2	3
	'81													1	2							2	3
Mo	'70																						
	'81																						
Na	'70																			1			
	'81																				1		
Ni	'70															1↔						1*	2*
	'81																		1				
Pb	'70																						
	'81																						
S	'70																						1
	'81																					1	
Zn	'70																						3
	'81																						

TABLE 27 . Pearson correlation coefficients inter-relationships for the combined bark samples of white birch, trembling aspen, and balsam poplar. Significance of correlations: 1 ≤ 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2 = Distance to Thunder Bay city; ALT = Altitude; D1 = Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		3	3										1								1*				1*																1*	1*					1*
ALT			3									1*									2*			1*														1*						1*			1*
D2									1*				1								1*				1*																1*						
'70 Fe								3		3		3		3		1		1		2				1		3		3		1				3				3		2				2		1	
'81 Fe								1		2		1*	3	3	1	1		2*		1						2								1					1				2		1	3	
'70 Mn							2								1	2	3*	3*	3*	1*	3*	3	3				1					2*	3*	1*	2*								2	1*	1*		3*
'81 Mn									1*					1	1		3*	3*	3*	1*	1*	3	3						1			1*	3*	1*	3*							1		1*	3*		
'70 P									1	3		3	2	2		3	2	2	3	3	2	1*	1*			3		3	1*	3		2		3	1			3						3	3	3	1
'81 P										1	3						2		2		3	1*	1*						1*			1	2						1						3		1
'70 N												2	2	2		2	1	2	2	3	1	1*	1*			3		1	1*	3	1			3	1									3	3	3	1
'81 N													1		1				1		3								1*																3		
'70 Al														2				1		2				2		2		3		1				3				3		3				2		1	
'81 Al														1		2				1						2								1					3				2		2	3	
'70 As															1		3*		2*				2			2		1		1			1*	1	1*	1		1		1		3				2	
'81 As																1*	3*	2*	2*	1*		2	3			1*					1	2*	1*	1*	2*			1*						1*	2		
'70 B																	3	3	3	3	2	3*	3*			3			1*			3	2	3	3							1*		1	1	3	1
'81 B																		3	3	2	3	3*	3*						2*			3	3	2	3							3*	2*	2	3		3
'70 Ca																			3	3	2	3*	3*			3						2	1	3	3	1								3		3	
'81 Ca																				3	3	3*	3*						2*			3	3	2	3							3*	2*	3	3		3
'70 Cd																					3	3*	3*			3		1				1	1	3	1									2		3	1
'81 Cd																						3*	3*						1*			3	3	2	2										3		3
'70 Cl																							3									3*	3*	2*	3*							2	2	3*	1*		3*
'81 Cl																										1*						3*	3*	2*	3*								2	2*	1*		
'70 Cr																									1									1		3		2		3	1	2					
'81 Cr																																				2				2	3	3					
'70 Cu																																1		3										2		3	
'81 Cu																																							3				2				
'70 F																																		3				3		1				1		1	
'81 F																																1*	1*		1*	1						1			2*		3*
'70 Hg																															3					1		1						3	3		
'81 Hg																																												2	3		
'70 K																																	3	2	1							1*	1*	1			1
'81 K																																			2							2*	2*				1
'70 Mg																																			3			3		1				2		3	1
'81 Mg																																										2*	2*		1		3
'70 Mo																																								3	2	2					
'81 Mo																																															
'70 Na																																								3				1			
'81 Na																																											1				
'70 Ni																																									1	2					
'81 Ni																																										1					
'70 Pb																																															
'81 Pb																																															
'70 S																																													3	2	
'81 S																																															1
'70 Zn																																															1
'81 Zn																																															

TABLE 28. Pearson correlation coefficients inter-relationships for all bark samples combined. Significance of correlations: 1 0.05, 2 ≤ 0.01, 3 ≤ 0.001. An asterisk indicates a negative correlation. D2= Distance to Thunder Bay city. ALT = Altitude. D1= Distance to Lake Superior.

	D1	ALT	D2	Fe		Mn		P		N		Al		As		B		Ca		Cd		Cl		Cr		Cu		F		Hg		K		Mg		Mo		Na		Ni		Pb		S		Zn	
				70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81	70	81
D1		3	3					1		1		1								1*	1*			1*	1*	1*		1*	1*										1		1*	2*		1*			
ALT			3															1*		1*	2*			1*	1*													1*		1*	1*	1*	2*	1*		1*	1*
D2									2*												1*				1*																1*	1*	1*		1*		
'70 Fe					3			2		2		3	3	3	3					2				2		2		2		1				3				3		3							
'81 Fe												1	3	2	3					1						1					2			1					2		1		2		1	1	
'70 Mn							3					1*				1*	2*	2*	2*		1*	3	3				2		1			1*	2*		1*							2	3				
'81 Mn								1				2*	1*			1	3*		3	2*		3	3						2	1*		1	2*	1	2*							3					
'70 P									3	3	3	3		3		3	3	3	3	3	3			2		3	3	3			1*	3	3	3	3			3		1		1		3	3	3	3
'81 P										3	3					2	3		2	2	3					3	3			1*		3	3		3				2					1	3		3
'70 N											3	2		3		3	3	3	3	3	3			2		2	3	3		1		3	2	3	3			3		1		2	1	3	3	2	3
'81 N																3	3	2	3	2	3			1		3	3			1		3	3	2	3							1	3	3	3	1	3
'70 Al													3	3	2					1		1*	1*	2		1		3		3			1*	3				3		3				1			1*
'81 Al															3																2		1*						3				1				2*
'70 As															3	1				1				2		3		3		3				2		1		3		2		3		3			
'81 As																												1																			
'70 B																	3	3	3	3	3	1	1*			3	3	3				3	3	3	3			2						3	3	3	3
'81 B																		3	3	3	3	2*	3*			3	3	3	1*	1*	2*	3	3	3	3			1	1					3	3	2	3
'70 Ca																			3	3	1	3*	3*	1		3	2			2	1	3	2	3	3	1				1				3	3	3	1
'81 Ca																				1	2	3*	3*			3	3	1	2		1	3	3	3	3				1			2*		3	3		3
'70 Cd																					3					3		2			3*	2	3	3	3										1	3	3
'81 Cd																							1			3	1			3*	3*	3	3	3	3										3	3	3
'70 Cl																							3				2		2	3*	2*	1*	2	1*	2*							3	3	1*			
'81 Cl																													1	2*	2*	1*	2*	1	2*							3	3				
'70 Cr																									3		1	2	1			1		2		3		2		3	3	3	1	3	1		
'81 Cr																													1							2				3	3						
'70 Cu																											3	3			1*	3	3	3	3			3		1		2		3	2	3	2
'81 Cu																												1		1*		3	2	2	2				1			1	3	3	3	1	2
'70 F																																3		3	2			3		2				3	1	2	
'81 F																														1*			1*			3						2			1*		
'70 Hg																															3		2*		1*			2						3		1*	2*
'81 Hg																																1*	2*	1*	2*										3	2*	3*
'70 K																																	3	3	3			3						3	3	1	3
'81 K																																		2	3									2	1	2	3
'70 Mg																																			3	1		3		3				3		3	3
'81 Mg																																							1					1	3	3	3
'70 Mo																																								3	1	3					
'81 Mo																																															
'70 Na																																								3				3			
'81 Na																																													1		
'70 Ni																																									3	3	1	2	1		
'81 Ni																																															
'70 Pb																																											3				
'81 Pb																																													3	1	
'70 S																																													3		
'81 S																																														1	3
'70 Zn																																															3
'81 Zn																																															

DISCUSSION

4.0 DISCUSSION

The major purposes of this report are to provide baseline data on elemental quantities in lichen and bark material and to determine if there has been any significant change in these quantities in the period involved from 1970 to 1983. Although the original proposal did not include determination of causes of change, where change does occur, there will be some hypotheses as to possible causes.

It is generally accepted that air pollution has continually increased during the 20th century (Gschwandtner et al., 1986). This argument is based on direct and indirect information from many sources. Generally, though, for any specific area there is little specific data to support specific conclusions. The study area of interest in this report is no exception. In southwest Thunder Bay District, pollutants such as sulphur and heavy metals can have several sources. One ubiquitous source is motorized vehicles. Another is various point sources such as pulp mills. There are also human populations throughout the area, varying from the relatively large population of Thunder Bay city to small villages and farmsteads. Even emissions from woodstoves can have a significant effect on air quality standards (Burnet et al., 1986). Finally, there is long range transport from various distant sources in Canada and the United States. All these sources result in the ambient pollutant levels of the past 10 - 20 years.

Sulphate deposition in the Thunder Bay area, for example, is thought to be 10 - 11 kg/ha/yr (Bird and Rapport, 1986). This level is 2 - 5 times what is considered to be natural background levels (Granat *et al.*, 1976). What, then, is the specific status of this 10,000 km² area during the past 10 - 20 years? Data from this report will be used as a basis for conclusions.

4.1 Lichens

The baseline lichen sample data for heavy metals (Table 3) show that all the lichen species do not accumulate metal elements at the same rate. Generally, *C. mitis* is least, with *Umbilicaria* spp. with increased and *P. sulcata* with the greatest amounts. This variability, with epilithic and epiphytic lichens having larger quantities than ground lichens is consistent with other studies, such as a Swedish inter-species comparative study (Folkeson, 1979) and Nieboer *et al.*, (1982) in Canada. The amounts found in the present study are generally what are considered "normal" by several authors (Bowen, 1966; Nieboer *et al.*, 1978; Kabata-Pendias and Pendias, 1984; Gailey *et al.*, 1985). However, Al and Fe levels are elevated in all the lichen species and As is elevated, at least in the 1970 samples, in all species.

When comparisons are made between the 1970 and 1983 sample sets, particularly with the *C. mitis* and the *P. sulcata* samples, most of the metals can be seen to decline from 1970 to 1983, and the *t* tests indicate that some of these decreases are significant (Table 5). Moreover, when all the lichen samples are combined, this large sample still has six elements that have significantly decreased: Cr, Fe, and Hg ($p = 0.01$); and Pb, Al, and As ($p = 0.001$). These data clearly indicate some decreases during the 13 years from 1970 to 1983.

The heavy metal Pearson correlations, when taken on a species basis, indicate that in most cases there is no correlation between the 1970 and 1983 samples (Tables 6 to 9). It is almost as though the sample sets were taken from different sites, or as if the sources of the various elements had changed during the 13 year period. When all the data are combined, though, most of the elements do have correlations between year data sets (Table 10). Still, however, Al, Fe, Cr, and Ni do not show any correlation. The lichen species correlation relationships with altitude and distance from Thunder Bay and Lake Superior are also not very clear. In a number of instances there are negative correlations with distance to Thunder Bay, which is to be expected if Thunder Bay is the major emission point source. However, the correlations that are present are at a low level of significance ($p = 0.05$) and are inconsistent from one group of data to another. There is then no clear relationship with Thunder Bay as a point source. Also, correlations between elements tend to be scattered and weak on a species basis. However, when all the data are combined (Table 10) there are many strong correlations, indicating that most of the elements do have the same sources.

Because the data are disparate it is tempting to conclude that long range transport, and not just various point sources, is important in determining heavy metal element concentrations. It is clear, though, that several heavy metal elements have decreased in lichen material since 1970.

Comparison of the lichen nutrient elements (Table 5) also shows most elements decreasing. Many of the decreases are significant in the smaller data sets, but when all the data are combined none of the elements is significantly different in 1983. Nutrient elements tend to be quite variable and only Mg has somewhat elevated levels when compared to levels in other studies (Bowen, 1966; Nieboer *et al.*, 1978; Larcher, 1980; Takala, *et al.*, 1985). The comments made above regarding the heavy metals can also be made for the nutrient elements. There is a general lack of correlation between 1970 and 1983 data sets; there is no clear relationships with any source for the accumulation of these elements, and there tend to be many inter-correlations when all species data are combined. It appears that there has been no real change in these nutrient elements during the study period.

4.2 Bark

The pH of bark is considered to be a good indicator of air quality once a suitable scale has been developed (Lötschert and Köhm, 1977; Grodzinska, 1979). Also, bark pH is an important habitat characteristic for epiphytic lichens (Barkman, 1958; Brown, 1982). Generally, deciduous trees are less acid than coniferous trees. There is, however, considerable variability in bark pH even in the same species. In Holland, Barkman (1958) found *Populus tremula* bark to vary from pH 3.9 to pH 7.9. Near Thunder Bay, white elm bark varied from 4.2 to 6.6 in a distance of less than 30 km (Barclay-Estrup and Sims, 1979). This variability is partly a result of normal site and age variability but it is also partly due to accumulation of particulates from emission sources. Except for black ash, the conifer and deciduous tree bark analyzed in this study and shown in Tables 11 and 12 is all quite acid when compared to other studies (Barkman, 1958; Skye 1968; Staxang, 1969). These same samples, when processed at Lakehead University in 1972 and 1981 were less acid (Tables 11 and 12). Some of the low pH differences may be owing to the fact that in the recent tests, the bark was pulverized in a Wiley Mill, while in the earlier study a kitchen blender was used, which resulted in larger particles. Rassmusen and Johnsen (1976) found that lower pH's result from more finely divided particles. There is no significant change in the bark pH's between species data sets for 1970 and 1981 (Tables 17,18 and 19). There is, though, a tendency for the bark of both conifers and deciduous trees to be less acid in 1981 than in 1970.

Most of the heavy metal element concentrations (Tables 13 and 14) seem comparable to those found in several other studies (Bowen, 1966; Young and Guinn, 1966; Fortescue and Martin, 1973; Kabata-Pendias and Pendias, 1984). Some elements (Fe, Hg, and Al) are, however, relatively elevated. The conifer bark heavy metal data shows a strong tendency towards decreased elemental content (Table 13). In particular, Fe, Hg, and As have large decreases. The deciduous bark heavy metal data (Table 14) shows Hg and As consistently decreasing. The paired *t* tests of these data for individual species show many decreases but few significant decreases (Tables 17 and 18). However, the combined data for conifer species show Al to decrease significantly ($p = 0.05$) (Table 19). Hg decreases very significantly ($p = 0.001$). As also has a large decrease but because the standard deviation of the 1981 samples is very large, this decrease is not significant. In the combined deciduous bark *t* tests (Table 19) both Hg and As decrease very significantly ($p = 0.001$). When all data are combined these three elements (Al, As, and Hg) all show significant decreases and the data definitely indicate reduction since 1970 of these metals.

Of the bark nutrient elements (Tables 15 and 16), only S appears to be elevated (Na is low) when compared with other studies (Bowen, 1966; Young and Guinn, 1966; Fortescue and Martin, 1973; Freedman *et al.*, 1982; Chatarpaul *et al.*, 1985; Takala *et al.*, 1985). These data for nutrient analyses also show inconsistent increases and decreases for most elements, but N, P and particularly S tend to decrease after 1970. When the data from all tree species are combined, *t* tests show that N and P have significantly decreased ($p = 0.01$) and S has very significantly decreased ($p = 0.001$) since 1970.

The Pearson correlation coefficients for the bark of individual tree species (Tables 20 to 25) do not show any really consistent relationships except perhaps for Cd which is often negatively correlated with distance from Thunder Bay and distance from Lake Superior, indicating Thunder Bay as a point source for this element. Cd is associated with such things as metal processing, rust proofing, and some fertilizers (Purves, 1977). In the combined data, however, more of the relationships for all elements become evident (Tables 26 to 28). Most of the elements have strong correlations ($p = 0.001$) between the 1970 and 1981 data sets, pointing to the same elemental sources in both years. Also, nutrient elements,(both metals and non-metals) are often strongly correlated to one another (i.e., Ca, K, Mg, Zn, Cu, B, N, P, and S). Cd is positively correlated with the nutrient elements but Mn and Hg tend to be negatively correlated to them. Cd is considered to be non-essential to plants but is easily absorbed by plant roots, leaves, and bark (Kabata-Pendias and Pendias, 1984). There are considerably fewer inter-relationships in other heavy metals, such as Ni, Pb, and Cr. In the metalloid As (included in the heavy metals in this report) there is good correlation only with Fe and Al. This is not unexpected, as As is strongly associated with Al, and especially with Fe, in soils (Kabata-Pendias and Pendias, 1984). An interesting set of correlations are those between distance from Lake Superior and altitude (these two variables are strongly correlated as generally the farther from Lake Superior, the higher the altitude). The heavy metals Cd, Cr, Ni, and Pb indicate a real relationship to distance from Lake Superior. The correlation is negative, indicating the lake as a source, but in another of the Great Lakes, Lake Michigan, (Sievering et al., 1981) the lake is shown to be a sink and not a source. Also, these data are opposite to those of Thornton et al., (1981), who showed a decreasing gradient of trace metals from western Minnesota to Lake Superior. Lake Superior has a strong local effect on the climate near Thunder Bay. This, plus the orographic effect of increasing altitude, could be affecting deposition rate. The indication of Lake Superior as a source of heavy metals may be an artifact but that there may be some lake effect is an intriguing possibility.

4.3 General Discussion and Conclusions

In a recent survey of forest-air pollution scientists, it is concluded that air pollution is not likely to decrease in the near future (Fraser et al., 1985). This present study of a relatively remote part of Ontario does not lead to the same conclusion. When both the lichen and bark results are taken together, some reasonably fact-based statements can be made. The elements Fe and Al, and probably also As, Hg, and S, were higher than expected at least in 1970. Some elements have decreased from 1970 levels. Al, Fe, Hg, As, N, and P have decreased, and probably Cr and Pb as well. Though no cause of these changes is definitely indicated by this study, a reduction in both local and distant long range transport of pollutants is probably involved. The study does indicate that Lake Superior may be having an effect on the deposition levels of some heavy metals (Cr, Cd, Ni, and Pb).

There is little historical evidence to support the theory that there has been a change in regional air quality near Thunder Bay. There is, however, some data that may indicate a change. Stottlemeyer (1981) recorded a precipitation pH of under 4.0 on Isle Royale and Thornton et al., (1981), also in 1979, reported SO_4 deposition as 14.8 kg/ha/yr at Hoveland, Minnesota. Both these stations are close to the study area, and if the current estimate of 10 - 11 kg/ha/yr for the Thunder Bay area is correct, then there has been a recent decrease in deposition levels. Also, Griffin (1975 and 1981) reports decreases in levels of some pollutants.

Lichens have long been considered to be excellent indicators of pollutant levels (Nieboer, 1981). Bark is also a good indicator, as trees accumulate heavy metals in their bark (Lötschert and Köhm, 1978; Grodzinska, 1982). Studies such as those of Skye (1982) show that reduced emission levels result in related chemical changes in the bark of trees. The present lichen and bark data have served two major purposes in this study. Baseline data has been provided for present and future comparison. Moreover, while comparisons of 1970-71 data with data from 1981-83 have shown that most elements are relatively unchanged, several elements, especially heavy metals, have evidently decreased during the study period.

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APPENDIX A

Site Locations and Descriptions

Appendix A. Site locations (Map B, page 7) and descriptions.

D-4	Shebandowan 1:50,000 map. Haines Township. Radio tower (105') on Highway 11 just southwest of Postans. The site is south of the highway 25 metres from the road and 50 metres east of the radio tower area and the line runs north and south. Mixed conifer-deciduous forest on an old cut-over area. Sparse to moderate shrub and herb layers but with moderate to good bryophyte layer.
E-4	Shebandowan 1:50,000 map. Hagey Township. South of Highway 11 and 2.2 miles west of the junction of Highway 11 with Highway 586. The site is 20 metres south of the highway and the line runs north and south. Mixed forest of conifers and deciduous trees but conifers are dominant. Moderate to dense shrub and small tree layer, with moderate herb cover and a well-developed bryophyte layer.
F-1-C	Raith 1:50,000 map. Robson Township. The site is 15 metres east of the main Great Lakes Paper Dog River Road, and is 3.2 miles from Highway 17. The line runs north and south. A mixed conifer-deciduous forest with a very dense shrub layer. The herb layer is well-developed but the bryophyte layer is sparse.
F-4-C	Sunshine 1:50,000 map. Blackwell Township. The site is 0.4 miles on the Isabella Road from Highway 11. The site is 25 metres west of the road and 25 metres south of the clearing for the 200 ft. radio tower. The line runs east and west. A mixed conifer-deciduous forest on a dry rocky area. There is a moderate shrub layer with a fairly well-developed shrub layer and patches of high bryophyte and lichen cover.
F-5-C	Kakabeka Falls 1:50,000 map. Sackville Township haul road. The site is 30 m south of the road and 0.8 km west of the Serpent Creek bridge. An open rock outcrop, facing north and moderately sloped. There is good bryophyte and lichen cover on the rock area which is surrounded by second growth mixed forest.

F-7-C	Pigeon River 1:50,000 map. Strange Township. The site is 85 metres west of the road to the Ministry of Natural Resources Campsite and Boat Launch on Whitefish Lake. The site is 50 metres north of Highway 588 and the line runs north and south.
G-1-C	Raith 1:50,000 map. Wardrope Township. This site is 7.7 miles from Hwy. 17 on a bush road to the Dog River (see map for details). The site is 20 metres north of the bush road and the line runs north and south. A mixed forest but predominantly conifers. The shrub layer is moderate to sparse with a moderate to good herb layer and a sparse to moderate bryophyte layer.
G-2	Raith 1:50,000 map. Robson Township. A logging road leaves the Trans Canada Highway 2 miles northwest of Raith and crosses the CPR and CNR tracks. The site is 0.4 miles from the CNR tracks and is 25 metres south of the road. The line runs north and south. A mixed forest, but mostly deciduous, on a hummock and hollow area. A rich area with a moderate to dense shrub stratum, a good herb layer and a sparse to good bryophyte layer with variability due to the hummock and hollow topography.
G-4	Sunshine 1:50,000 map. Goldie Township. The site is west of Highway 17, 3.6 miles north of the junction of Highway 11 & 17 (Shabaqua Corners). It is 80 metres west of the highway and the line runs southeast to northwest. This is a mixed forest but is primarily a Jack Pine and Aspen stand on a well-drained hillside. The shrub layer is moderate to dense with a moderate herb layer and some good patches of bryophytes.
G-4-C	Sunshine 1:50,000 map. Dawson Road Lots. The site is on a side road 2.9 miles from the junction of Highway 11-17 and the Finmark Road. The site is 25 metres south of the sideroad and the line runs in a northwest to southeast direction. A mixed forest but mostly conifers on a north-east-facing hillside. The shrub layer, the herb layer, and the bryophyte layer all tend to be sparse.

G-8	Pigeon River 1:50,000 map. Lismore Township. The site is on the Devon Road (Highway 593) and is 5.2 miles south of the junction with Highway 588. The site is 15 metres east of the road and the line runs north and south. A mixed forest on a well-drained hillside with a moderate to dense shrub layer and a quite well-developed herb stratum, but few bryophytes.
G-8-E	Pigeon River 1:50,000 map. Fraleigh Township. The site is 25 m north of the road to Fallingsnow Lake, at the base of the hill 2.1 km from the lake. Mature mixed forest on a level well drained site. Both the shrub layer and the herb layer are well developed.
G-9-E	Pigeon River 1:50,000 map. Devon Township. This site is on the Devon Road (Highway 593) and is 6.8 miles from the junction of the Devon Road and the Pigeon River Road. The line runs north and south and the site is 10 metres south of the road. A mixed forest but primarily Trembling Aspen. There is a moderate shrub layer and a very well-developed herb layer. The bryophyte stratum is sparse.
H-3-C	Sunshine 1:50,000 map. Fowler Township. The site is 3.0 km from the control gate (Dog Lake Picnic Area) on the road to the Dog Lake Dam. The *Cladina* area is 10 m west of the road and the *Parmelia* area is 30 m west of the road. The rock area is an open outcrop with good lichen and moss cover and surrounded by mixed forest trees. The forest is mixed in a generally flat area with wet depression and drier higher rocky rises. There is a well-developed shrub layer and often good moss cover as well.
H-4	Sunshine 1:50,000 map. Forbes Township. The site is the old homestead road (now a logging road) 9.5 km north of the Finmark CPR crossing. The *Parmelia* collection made mostly west of the road but some to the east as well. Cutover mixed forest in a relatively flat area. There is a good shrub layer and a good herb layer.
H-5-C	Kakabeka Falls 1:50,000 map. Conmee Township. 40 m south of Brulé Creek Road (east of Highway 11-17), at the bridge crossing Brule' Creek.

	A mixed conifer-deciduous forest, partly cutover, on a rather dry north-facing hillside. There are good shrub and herb layers and also good bryophyte and lichen areas.
H-6	Kakabeka Falls 1:50,000 map. Conmee Township 0.32 km west of 3rd crossroad on Blind Line Road west of Highway 11-17. Site is 40 m north of the road. A mixed swampy forest area mostly cedar, tamarack and speckled alder. Birch for Parmelia collection is scarce.
H-7-C	Kakabeka Falls 1:50,000 map. Scoble Township. On the top of the cliffs at the west end of Oliver Lake north of the public access area. Flat open flat rock area about 20 m north of the cliff top surrounded by a mixed jack pine and aspen forest.
H-9	Pigeon River 1:50,000 map. Devon Township. This site is 30 metres north of the Devon Road (Highway 593) 3.2 miles from the junction of the Devon Road and the Pigeon River Road. The line runs northwest-southeast. This is a good mixed forest site with well-developed shrub and herb strata. The bryophyte layer is generally sparce.
H-9-E	Pigeon River 1:50,000 map. Pardee Township. East facing cliffs 150 m east of Lenore Lake. Small open rock areas partly surrounded by shrubs and a mixed forest, open to the east.
I-3-C	Onion Lake 1:50,000 map. Fowler Township. 160 m on Hwy. 591 west of the Hawkeye Lake Biogeochemical Study Site access road. The site is at the top of the ridge 60 m south of the road. This is a mixed forest with sparce to moderate shrub and herb layers.
I-4-C	Onion Lake 1:50,000 map. Ware Township. This site is on a road 0.2 miles north of the road that runs west from Lappe (there is no name, but see the map for details). The site is 25 metres west of the road and the line runs east and west. A mixed forest with a moderate to dense shrub layer, with both a good herb layer and a good bryophyte-lichen layer.

I-6	Kakabeka Falls 1:50,000 map. Oliver Township. The site is 1 km north of Hwy 130 and 25 m west of Corbett Creek Road (just north of the bridge). The site is a swampy mixed forest area. There are well developed shrub and herb layers.
I-7	Kakabeka Falls 1:50,000 map. Paipoonge Township. The site is 35 m south of the road on the south end of Candy Mountain and is 0.1 km east of the Paipoonge-Scoble boundary. This is a mixed forest with moderately developed shrub and herb layers.
I-7-C	There are two collection areas, one for *Parmelia* and the other for *Cladina* and *Umbilicaria.* The *Parmelia* area is on the Jarvis River 1:50,000 map in Blake Township. The site is 2.4 km on Blake Hall Road from Hwy 61 and it is 30 m south of the road. This is a mixed forest with well-developed shrub and herb layers. *Cladina* - *Umbilicaria* area is on the Pigeon River 1:50,000 map in Scoble Township. The site is 2.7 km from Hwy 61 and is 50 m east of Hwy 608. The site is an open rock area near the top of the west facing cliff. Jack pine and aspen are around the open areas.
I-8	Pigeon River 1:50,000 map in Pearson Township. The site is on a rock ridge 100 m east of Hwy 597. The collection site is an open area at the top of ridge. Shrubs and some small aspen are around the site.
I-8-S	Pigeon River 1:50,000 map. Pardee Township. The site is on a side road 0.5 miles east of Highway 597. The site is 30 metres south of the road and the line runs east and west. A mature mixed forest, mostly deciduous, on a rich site. Dense shrub and herb layers with a mostly sparse bryophyte layer.
I-9-S	Pigeon River 1:50,000 map. Crooks Townships. This site is on the Little Pigeon Bay Road 1.5 miles from Highway 61. The site is 25 metres east of the road and the line runs east and west. A mixed forest, but mostly conifers, with sparse to moderate shrub and herb layers and mostly

	sparse bryophytes as well.
I-9-E	Jarvis River 1:50,000 map. Crooks Township. This site is 4.1 miles on the Cloud River Road from Highway 61. The site is 40 metres east of the road and the line runs north and south. A mixed forest on a rough rocky area. There is a moderate to dense shrub and small tree layer with a moderate herb layer. Bryophytes and lichens are sparse to some patches of high cover on rocks.
J-3	East Bay 1:50,000 map. The site is 0.25 km south of the resort at the end of the road. The site is 15 m west of the road. This is a mixed forest in a low area near the lake. There are good shrub and herb layers but bryophytes and lichens are mostly sparse.
J-3-C	Onion Lake 1:50,000 map. Jacques Township. This site is near Sunday Lake 1.6 miles from the Howcum Lake Road. The site is 65 metres west of the Sunday Lake Road and the line runs north and south. A mixed, but mostly conifer, forest with a moderate to dense shrub layer and a good herb layer. There is a moderately well-developed bryophyte layer as well.
J-4	Onion Lake 1:50,000 map. Jacques Township. This site is near Two Island Lake 1.3 miles west on Island Lake Road from Highway 589. The site is 30 metres north of the road and the line runs north and south. This is a mature mixed stand with a sparse to moderate shrub, herb, and bryophyte cover.
J-5	Onion Lake 1:50,000 map. Gorham Township. The site is on a side road 1.0 km west of Hwy 589. The sideroad is 3.6 km south of Lappe. The site is 50 m south of the sideroad. This is a swampy mixed forest. The shrub layer is moderate as is the herb and ground layers.
J-5-C	Thunder Bay 1:50,000 map. McIntyre Ward. This site is 10 m south of the north facing cliff north of the Ministry of Transport enclosure on Rabbit Mountain. This is an open flat rock area. A lichen-moss-dwarf shrub heath.
J-6	Thunder Bay 1:50,000. McIntyre Township. The site is 100 metres northeast of the Jack Pine Community Hall just off Oliver Road. The line runs NNW to SSE. A mixed forest in a mostly

	swampy, hummock and hollow area. There is moderate shrub and herb cover with some patches of bryophytes.
J-6-C	Thunder Bay 1:50,000 map. Fort William Indian Reserve. The site is 150 m northwest of the ski house at the top of the main Mt. McKay Chair Lift. This is a large talus slope at the base of a northwest facing cliff. Some birch and aspen are at the edge of the slope.
J-8-S	Jarvis River 1:50,000. Crook Township. The site is about 100 m southeast of the road, near the top edge of a steep northeast facing cliff. This is a rocky shallow soil area with a mixed forest surrounding the open rock collecting areas.
K-3-C	Onion Lake 1:50,000 map. The site is 15.7 miles on Highway 800 from the junction with Highway 11-17. The site is 25 metres west of the road and the line runs north and south. A mixed forest but primarily Jack Pine on a rather dry site on an old burn area. The shrub and herb strata are sparse to moderate with some good areas of bryophytes.
K-4	Onion Lake 1:50,000 map. Gorham Township. The site is on the west side of the Onion Lake Dam up the hill about 100 m. This is a mixed forest on a moderately steep south facing slope. There is good *P. sulcata* cover on the white birch trees.
K-4-C	Onion Lake 1:50,000 map. Shuniah Township. There are two collection areas - one for *P. sulcata* and one for *U. muhlenbergii* and *C. mitis.* The *Parmelia* area is 100 m southeast of Hwy. 527, 16 km north of Hwy 11-17. This is a mixed forest on a northwest facing hillside. The *Umbilicaria* and *Cladina* area is at the same location, but is about 200 m from Hwy. 527 on the west shore of a small lake. There are open rock outcrops partly surrounded by mixed forest.
K-5	Onion Lake 1:50,000 map. Gorham Township. There are two sites (close together), one for *Parmelia* and one for *Cladina*. Both sites are on Wild Rose Road (off the Copenhagen Road). The *Parmelia* site is 50 m south of Wild Rose Road and 50 metres west of Copenhagen Road. The *Cladina* site is 15 m north of Wild Road Road and

	100 m from Copenhagen Road. Both sites are mixed forest but the Cladina site has open rock areas in the forested area.
K-5-C	Onion Lake 1:50,000 map. Shuniah Township. The site is 50 m south of Lakeshore Drive and 0.4 km east of the Wild Goose Hotel. This is a swampy mixed forest with considerable speckled alder and willow present.
K-6-C	Thunder Bay 1:50,000 map. Welcome Islands. The site is on the most easterly point of the Welcome Islands about 200 metres south of the lighthouse and 20 metres west of the lakeshore. The line runs northeast - southwest. A mature mixed forest, dominated by Balsam Fir and White Birch, on a rocky area. The shrub and herb layers are moderate to sparse with a well-developed bryophyte layer.
K-8	Jarvis River 1:50,000 map. Pic Island. The original 1971 site was not located but a new site in a very similar area was established and soil and bark samples taken. The site is 40 metres west of the old logging camp clearing and 15 metres south of the old logging road (25 metres north of the lakeshore). The line runs east and west. A mature mixed stand of mostly Balsam Fir and White Birch with sparse to moderate shrub, herb, and bryophyte layers.
M-3-C	Loon 1:50,000 map. Shuniah Township. This site is 50 m east of the road to the amythest mine on Elbow Lake. The site is at the north end of a small lake 0.3 km south of the gate to the mine area. This is a swampy mixed forest with open rock outcrops near the lake.
M-4	Loon 1:50,000 map. McTavish Township. The site is on the West Loon Road 0.8 miles west of the railway crossing. The site is 50 metres southwest of the road and the line runs northwest-southeast. A mixed stand in a flat, wet hummock and hollow area. The shrub stratum is moderate to dense with sparse to moderate herb and bryophyte strata.
M-4-C	Loon 1:50,000 map. Shuniah Township. There are two close-together collecting sites. The Parmelia site is 15 m west of Hwy. 587 and just

	north of the Bak Road. This is a mixed forest area. The *Umbilicaria* and *Cladina* site is east at the top of the cliff east of the picnic area, east of Hwy 587, and east of the railway. There are open rock areas surrounded by a mixed forest on shallow soil.
M-5-C	Thunder Cape 1:50,000 map. Sibley Township. The site is 50 metres south of the road to Poundsford Lake and 4 km from Highway 587. This is mature mixed forest on shallow soil over a broken rock area. There is a good shrub layer with good areas of herb species as well as substantial feather moss areas.
M-6-C	Thunder Cape 1:50,000 map. Sibley Township. There are two collecting sites about 3 km apart. The *Parmelia* site is 15 m north of the tote road to Middlebrun Bay. The site is 150 m west of the bay. This is a mixed forest site on sandy well-drained soil. The *Umbilicaria* and *Cladina* site is on the top of the rock bluffs about Hwy. 587 and west of the south end of Grassy Lake. Mixed forest surrounds the open rock area. Both *Umbilicaria* and *Cladina* are sparse at this site.
N-2-C	Greenwich Lake 1:50,000 map. Dorion Township. This site is on the road to the Dorion Fish Hatchery and is 2.2 miles from Highway 11-17. The site is 25 metres north of the road and the line runs north and south. A rich mixed forest on a wet site with hummocks and hollows. Dense shrubs and a well-developed herb layer. The bryophyte layer is sparse to moderate.
N-3	Greenwich Lake 1:50,000 map. Dorion Township. This site is on the road to the Ouimet Canyon Lookout and is 6.7 miles from Highway 11 and 17. The site is 70 metres north of the road and the line runs north and south. A well-developed mixed forest on a rather dry shallow soil site. The shrub stratum is moderate with a well-developed herb layer and some patches of both bryophytes and lichens.
N-3-C	Loon 1:50,000 map. Shuniah Township. This site is at the base of cliffs 100 m west of the south end of Ancliff Lake (2 km south of Hwy. 11-17). This site is on large rocks at the base of an east facing cliff. The area is bordered by a mostly hardwood forest.
N-5	Loon 1:50,000 map. Sibley Township. There are two collecting sites about 2 km apart. The

Parmelia site is 50 m east of Squaw Bay Road at the cottage access road to Moonlight Beach on Louse Cove. This is a mixed forest. The Cladina site is 2 km south of the Parmelia site 15 m west of the road. There are rock outcrops in a mixed forest.

N-6 Thunder Cape 1:50,000 map. Sibley Township. This site is in Sibley Provincial Park 150 m west of Highway 587 and 4.4 km south of the Poundsford Lake Gatehouse. The site is in a flat area over the top of the hill. The line runs north and south. A rich mixed forest that contains some large White Pine. There is a moderate shrub layer and a well-developed herb layer. Bryophytes are sparse to moderate.

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